THE CORKY RINGSPOT DISEASE OF POTATOES: BIOLOGY OF *Trichodorus christiei* AND *Trichodorus proximus* AND EVIDENCE FOR THE EXISTENCE OF UNSTABLE TOBACCO RATTLE VIRUS IN CORKY RINGSPOT-INFECTED POTATOES

By

ROBERT E. HARRISON

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL
OF THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1975

ACKNOWLEDGMENTS

I extend my sincere appreciation to the following people, without whose guidance and assistance this project would not have been possible:

Dr. G. C. Smart, Jr., my committee chairman, who devoted a great deal of time and effort to the direction of my research and to the preparation of this manuscript;

Dr. V. G. Perry, Dr. D. P. Weingartner and Dr. F. W. Zettler, my committee members, who offered valuable assistance and criticisms;

Dr. D. Pring, who directed the phenol extractions of TRV;

Dr. A. C. Tarjan, who served as a member of the examining boards for my preliminary and final examinations;

Dr. J. A. Cornell, who directed the statistical analysis of my experimental data.

TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS.....ii

LIST OF TABLES..... v

LIST OF FIGURES.....vii

ABSTRACT..... x

INTRODUCTION..... 1

Disease Symptoms..... 2

The Nematode Vector: *Trichodorus* Cobb, 1913..... 3

The Virus: Tobacco Rattle Virus (TRV) Quanjer, 1943..... 8

Control of Potato Corky Ringspot Disease.....11

Purpose of this Study.....11

MATERIALS AND METHODS.....12

Population Dynamics of *Trichodorus christiei* and *T. proximus* in a potato field.....12

Nematode Inoculum.....12

Virus Inoculum.....15

Soil Used in Laboratory Experiments.....15

Laboratory Procedures for Plant Maintenance.....15

Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers Tomato, Sebago Potato and Pungo Potato.....15

Vertical Distribution of *Trichodorus christiei* and *T. proximus* in PVC columns.....16

Effects of Soil Moisture on Survival and Reproduction of *Trichodorus christiei* and *T. proximus*.....16

Effects of Soil Collected at Different Depths on Survival and Reproduction of *Trichodorus christiei* and *T. proximus*.21

Page

Movement of *Trichodorus christiei* and *T. proximus* Through Soil....22

Determination of Soil Properties....22

Isolation of Tobacco Rattle Virus....27

RESULTS....30

Population Dynamics of *Trichodorus christiei* and *T. proximus* in a Potato Field....30

Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers Tomato, Sebago Potato and Pungo Potato....61

Vertical Distribution of *Trichodorus christiei* and *T. proximus* in PVC columns....61

Effects of Soil Moisture on Survival and Reproduction of *Trichodorus christiei* and *T. proximus*....75

Effects of Soil Collected From Different Depths on Survival and Reproduction of *Trichodorus christiei* and *T. proximus*....75

Movement of *Trichodorus christiei* and *T. proximus* Through Soil....75

Determination of Soil Properties....88

Isolation of Tobacco Rattle Virus....88

DISCUSSION....99

LITERATURE CITED....105

BIOGRAPHICAL SKETCH....112

LIST OF TABLES

Table Page

1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm, ARC Hastings, Florida................. 33

2. Correlation of field populations of *Trichodorus christiei* and *T. proximus* with depth in the soil: correlation coefficients / Prob 1R1 under HO: RHO = 0.. 59

3. Correlation of field populations of *Trichodorus christiei* and *T. proximus* with soil moisture: correlation coefficients / Prob 1R1 under HO: RHO = 0.. 62

4. Correlation of field populations of *Trichodorus christiei* and *T. proximus* with soil pH: correlation coefficients / Prob 1R1 under HO: RHO = 0.. 63

5. Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers tomato, Sebago potato and Pungo potato (mean of 6 replicates; 500 specimens used as inoculum)............................ 64

6. Correlation of populations of *Trichodorus christiei* in vertical PVC columns with soil depth and soil moisture: correlation coefficients / Prob 1R1 under HO: RHO = 0............. 73

7. Correlation of populations of *Trichodorus proximus* in vertical PVC columns with soil depth and soil moisture: correlation coefficients / Prob 1R1 under HO: RHO = 0............. 74

8. Correlation of laboratory populations of *Trichodorus christiei* with soil moisture (t values).. 76

9. Correlation of laboratory populations of *Trichodorus proximus* with soil moisture (t values).. 78

Table | Page

10. Texture of soil from Bed Four, Yelvington farm (new land), ARC Hastings, Florida................ 80

11. Effects of soil collected from different depths on survival and reproduction of *Trichodorus christiei* (mean of 6 replicates).......... 81

12. Effects of soil collected from different depths on survival and reproduction of *Trichodorus proximus* (mean of 6 replicates)........... 82

13. Properties of soil from Bed Four, Yelvington farm (new land), ARC Hastings, Florida (mean of 6 replicates)................................ 89

14. Reactions of test plants to inoculation with sap from suspected TRV-infected tissue samples (data represent 6 replicates)......................... 92

15. Reactions of test plants to inoculation with sap from plants previously inoculated with sap from suspected TRV-infected tissue samples (data represent 2 replicates)......................... 93

16. Results of attempts to isolate TRV from plants fed upon by the nematodes *Trichodorus christiei* and *T. proximus* (data represent 6 replicates)......... 94

17. Results of test plants to inoculation with phenol extracts from corky ringspot-affected Sebago potatoes (data represent 2 replicates)........ 98

LIST OF FIGURES

Figure Page

1. Bed Four, Yelvington farm (new land) during potato-growing season.................................. 14

2. Bed Four, Yelvington farm (new land) during cover-cropping season.................................. 14

3. PVC column used in determining vertical distribution of *Trichodorus christiei* and *T. proximus*... 17

4. Constant-moisture funnel design........................ 18

5. Constant-moisture funnels in operation................. 20

6. Nematode horizontal movement box....................... 20

7. Recovery zones of *Trichodorus* spp. from horizontal movement box................................ 23

8. Seasonal population fluctuations of *Trichodorus christiei* in a potato field (Bed Four, Yelvington farm, ARC Hastings, Florida)................ 31

9. Seasonal population fluctuations of *Trichodorus proximus* in a potato field (Bed Four, Yelvington farm, ARC Hastings, Florida)................ 32

10. Correlation of *Trichodorus christiei* and *T. proximus* with soil depth............................... 60

11. Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers tomato.......................... 66

12. Damage to Rutgers tomato roots caused by *Trichodorus christiei* and *T. proximus*.................. 66

13. Mean vertical distribution of *Trichodorus christiei* in PVC columns with 1.0 m water tables... 67

14. Mean vertical distribution of *Trichodorus christiei* in PVC columns with 1.25 m water tables.. 68

Figure Page

15. Mean vertical distribution of *Trichodorus christiei* in PVC columns with 1.5 m water tables.. 69

16. Mean vertical distribution of *Trichodorus proximus* in PVC columns with 1.0 m water tables.. 70

17. Mean vertical distribution of *Trichodorus proximus* in PVC columns with 1.25 m water tables.. 71

18. Mean vertical distribution of *Trichodorus proximus* in PVC columns with 1.5 m water tables.. 72

19. Effects of soil moisture on survival and reproduction of *Trichodorus christiei*; 100 specimens used as inoculum.............................. 77

20. Effects of soil moisture on survival and reproduction of *Trichodorus proximus*; 100 specimens used as inoculum.............................. 79

21. Horizontal movement of *Trichodorus christiei* and *T. proximus* from an inoculation point toward the root zone of a Rutgers tomato plant.. 83

22. Distribution of *Trichodorus christiei* in horizontal movement box 36 hours after inoculation into the center of the box................. 84

23. Distribution of *Trichodorus proximus* in horizontal movement box 36 hours after inoculation into the center of the box................. 85

24. Distribution of *Trichodorus christiei* in horizontal movement box 72 hours after inoculation into the center of the box................. 86

25. Distribution of *Trichodorus proximus* in horizontal movement box 72 hours after inoculation into the center of the box................. 87

26. External symptoms of corky ringspot on *Solanum tuberosum* 'Sebago'............................ 91

27. Internal symptoms of corky ringspot on *Solanum tuberosum* 'Sebago'............................ 91

Figure Page

28. Virus particles observed in corky ringspot-affected Sebago tubers.............................. 97

Abstract of Dissertation Presented to the
Graduate Council of the University of Florida in
Partial Fulfillment of the Requirements for the
Degree of Doctor of Philosophy

THE CORKY RINGSPOT DISEASE OF POTATOES: BIOLOGY OF *Trichodorus christiei* AND *Trichodorus proximus* AND EVIDENCE FOR THE EXISTENCE OF UNSTABLE TOBACCO RATTLE VIRUS IN CORKY RINGSPOT-INFECTED POTATOES

By

Robert E. Harrison

August, 1975

Chairman: G. C. Smart, Jr.
Major Department: Entomology and Nematology

Soil cores taken at 10-cm increments to a depth of 150 cm were collected every two weeks from a potato field near Hastings, Florida, from 2 March 1974 to 15 February 1975. Fluctuations in populations of *Trichodorus christiei* and *T. proximus* were non-significant during both the potato and the cover crop seasons. Highest densities of *T. christiei* occurred at 10 to 40 cm and of *T. proximus* at 20 to 50 cm. Soil moisture at 10 to 50 cm depths ranged from 20 to 29% by weight. No nematodes were found below the water table, which varied from 50 to 180 cm during the sampling period.

Survival and reproduction of *T. christiei* was greatest at 10% moisture and that of *T. proximus* at 20% when the nematodes were allowed to feed on Rutgers tomato plants grown at constant soil moisture levels of 0, 10, 20, 30 or 40% by weight. No specimens of either species

survived at 0% moisture and very few at 40% moisture.

Vertical distribution patterns of *T. christiei* and *T. proximus* were studied in the laboratory by placing 500 specimens of either species at the top or at the bottom of 10 X 175 cm columns filled with sterile Rutlege fine sand and planted with a 40-day-old Rutgers tomato seedling. Water tables were maintained at either 100, 125 or 150 cm below the soil surface. After 75 days, 71% of the *T. christiei* population was found at 10 to 60 cm depths, whereas 68% of the *T. proximus* were in the 10 to 40 cm sections. No nematodes were found below the water tables.

In pathogenicity studies, both *T. christiei* and *T. proximus* significantly reduced fresh weights of Rutgers tomato, but neither significantly affected 'Sebago' or 'Pungo' potatoes, *Solanum tuberosum L.*

Population levels of both *T. christiei* and *T. proximus* were significantly higher when reproduction and survival experiments were performed in soil collected from 0 to 90 cm depths than in soil collected from greater depths.

Studies of the movement of *T. christiei* and *T. proximus* showed that after 36 hours, an average of 15% of the *T. christiei* and 39% of the *T. proximus* placed into a horizontal migration box had moved 25 cm to the root zone of a Rutgers tomato bait plant; after 72 hours, an average of 44 and 56%, respectively, had done so. Relatively few nematodes were found in any of the sections outside a narrow band between the inolulation point and the root zone of the plant, indicating not only attraction but a relatively direct approach to the plant.

All attempts to isolate the stable form of tobacco rattle virus from corky ringspot-affected potatoes failed. However, symptoms appeared on test plants when inoculated with phenol extracts from the same potatoes, suggesting the presence of an unstable form of TRV within the Hastings isolate.

INTRODUCTION

The corky ringspot disease (CRS) of potato was first described and illustrated by Atanasoff (5) as internal brown spot or "spraing" on potatoes from Europe, the Dutch Indies, South Africa and Canada. The first observation of CRS in the United States was reported by Eddins, Proctor and West (23) in 1946 from the potato-growing area of Hastings, Florida. Walkinshaw and Larson (79), in 1958, found a sap-transmissible rod-shaped virus to be associated with diseased tubers from Hastings. They named the virus "potato corky ringspot virus" (PCRV) and established serological relationships between PCRV and potato stem-mottle virus and tobacco rattle virus (TRV) from the Netherlands. Walkinshaw, Griffin and Larson (78) reported in 1961 that PCRV is, in fact, an American strain of TRV.

The erratic occurrence of CRS under natural conditions and the inability to increase transmission by adding large amounts of virus to sterilized soil led to the hypothesis that a nematode vector was involved in disease spread (78). In 1961, Walkinshaw, Griffin and Larson (78) demonstrated that the nematode *Trichodorus christiei* Allen, 1957 is a vector of PCRV. They observed virus symptoms on indicator plants after the introduction of viruliferous nematodes and also reported a high incidence of transmission which was related directly to the number of nematodes introduced.

Disease Symptoms

Symptom expression and disease severity of CRS varies due to the variation of TRV isolates (38).

External symptoms of CRS are in the form of ringspot lesions scattered over the tuber surface. Walkinshaw and Larson (80) described these lesions as external manifestations of arcs of necrotic tissue which extend into the tuber flesh. Walkinshaw and Larson (80) also stated that deep growth cracks, severe distortion, extensive suberization and irregular shallow furrows of suberized tissue often occur on the tuber surface.

Walkinshaw and Larson (80) described the internal symptoms of CRS as "...concentric arcs, rings or line patterns of necrotic tissue which tend to follow external patterns. Small blotches of dead tissue may occur in the flesh, but these areas are restricted, in most cases, to the outer portions of the tuber." Highest concentrations of TRV have been found in the necrotic areas of the tubers (80).

Foliage symptoms have been observed in the form of severe stunting of the leaves and stems, elongated leaflets and a yellow mottle which is most prominent in the youngest leaves (80). According to Walkinshaw and Larson (80), "...the more severe the tuber symptoms, the less often symptoms are observed in the foliage. Conversely, the less severe the tuber symptoms, the more often symptoms occur in the foliage." To date, foliage symptoms in the United States have been observed only in greenhouses at low temperatures (16 to 24 C) (44,80).

In some potato-growing areas of the United States, tubers show internal necrosis but rarely arcs and rings of necrotic tissue. In these areas there have been few external tuber symptoms and no foliar symptoms (21,47).

Tubers can develop symptoms during storage, particularly in warm storage for chip potatoes (23).

In progeny plants of infected tubers, symptoms are limited to internal arcs of necrotic tissue extending outward from the vascular tissues. These arcs are more concentrated near the stem end of the tuber (80).

The Nematode Vector: *Trichodorus* Cobb, 1913

The first specimen of *Trichodorus* was described in 1880 by de Man (50), who named it *Dorylaimus primitivus* de Man. The genus *Trichodorus* was established by Cobb (17) in 1913, with the description of *T. obtusus* Cobb. Micoletzky (53), in 1922, redescribed *D. primitivus* as *T. primitivus*, and placed *T. obtusus* in synonymy. The number of species in the genus has now reached 35. Siddiqi (69) recently erected the genus *Paratrichodorus*, in which he placed 18 species previously under *Trichodorus*.

Trichodorus species are thick-bodied (0.5 to 1.5 mm long; 0.03 to 0.08 mm wide). The onchiostyle is in the form of a nonaxial tooth which is grooved rather than hollow (59). Male and female tails are short and bluntly rounded. The cuticle is smooth, not marked by lines or punctations. Both males and females may have body pores which vary in number and position among the known species. The esophagus is in the form of an anterior slender tube which expands gradually to form an elongate conoid swelling. Five esophageal glands are present. Measurements of specimens within a species may be highly variable. Bird and Mai (7) found morphometric differences in a population of *T. christiei* fed on different host plants.

The economic importance of *Trichodorus* was recognized in 1951, when Christie and Perry (16) found *T. christiei* injuring the roots of beets, celery and sweet corn near Sanford, Florida. Subsequent pathogenicity tests and host lists have revealed that *T. christiei* is polyphagous, causing damage to many vegetable, legume, grain and ornamental plants (1, 19, 33, 50, 64, 71, 74, 88, 89). Several other species of *Trichodorus* also have been the subjects of pathogenicity studies. Jensen and Konicek (39) concluded that *T. allius* Jensen, 1963 is an important pest of onion in Oregon, and Rhoades (61) found *T. proximus* Allen, 1957 involved in a disease of St. Augustine grass in Florida. In Britain, *Trichodorus* species are associated with the "docking disorder" of sugar beets (85). Stunting of sugar beets in the Netherlands was associated with *T. teres* Hooper, 1962 (45). By direct observations through viewing ports of a laboratory built underground, Pitcher (57) and Pitcher and Flegg (58) found that *T. viruliferus* Hooper, 1963 masses at the root tips of apple, caused necrosis, halted growth and caused some swelling of the tips.

Aboveground symptoms of attack by *Trichodorus* are similar to those of most other plant parasitic nematodes feeding on the roots; that is, foliage is chlorotic and plants are stunted and appear in various stages of decline. Damage in field plantings appears in slowly widening circles (15).

Severe injury usually occurs to the root systems of plants attacked by *Trichodorus*. Brown lesions may appear at the feeding site and root tips may be destroyed or reduced to an abnormal swelling that ceases to grow (62).

Adults of *Trichodorus* species are root ectoparasites, feeding mainly on epidermal cells at root tips, but also along the sides of young roots (16, 64, 89). Russell reported that *T. christiei* penetrated the root cap and fed in the apical meristem region of wheat, *Triticum aestivum* L., roots growing on an agar medium.

Trichodorus species feed on plant cells by repeatedly thrusting the onchiostyle into the epidermal cells of the host root (14, 62, 64, 86, 88, 89). Rohde (62) suggested that feeding by *T. christiei* reduced or stopped cell division in the meristem while differentiation of existent cells progressed normally, causing swelling of the root tips, or "stubby root". Hoff (32) found that the increase of cortex size in "stubby root" was a result of abnormal cell maturation instead of cessation of cell division. Others (64, 71, 89) reported that *T. christiei* may stimulate cell division in the pericycle, resulting in flattened and abnormally enlarged rootlets. Zuckerman (88) stated that sometimes there is an indication, in the swollen root tips, that one or more adventitious root laterals had been stimulated into temporary growth.

Few reports of factors affecting the life cycle of most *Trichodorus* species have been published. The life cycle of *T. christiei* was studied by Rohde and Jenkins (63, 64) who found that 21 to 22 days were necessary for the completion of one life cycle at 22 C, while at 30 C one life cycle was completed in 16 to 17 days. Bird and Mai (8) and Malek, Jenkins and Powers (49) recorded greatest population increases at 25 C. Ayala (6) reported maximum reproduction of *T. christiei* at 16 to 24 C.

The vertical distribution of *Trichodorus* species in the soil seems to be highly variable but may be related to soil temperature and texture. Hoff and Mai (34) recovered *T. christiei* in New York only from depths of 0 to 12 inches throughout the year. Brodie and Quattlebaum (11) reported highest numbers of *T. christiei* in Georgia at depths of 15 to 30 cm, the depth distribution being greatly influenced by soil texture. In the Netherlands, *T. teres* was found at depths of 30 to 50 cm in winter and spring months, but, in the summer and fall, most were nearer the soil surface (73). Szczygiel and Hasior (72) reported highest numbers of *T.*

primitivus, *T. pachydermus* Seinhorst, 1954 and *T. similis* Seinhorst, 1963 at depths of 10 to 40 cm, with high numbers as deep as 62 cm. Pitcher (57) found that *T. viruliferus* massed around the zone of elongation of apple roots and that the mass of nematodes followed the growing root, remaining one to three millimeters behind the tip.

Trichodorus species occur in a number of different soil types, but they have been found mainly in open-textured soils. *T. christiei* has been reported from a number of soil types in the United States including muck (15, 48) and clay loam (8), but the preferred soil type appears to be light sand. In the Netherlands, *T. teres* is found in sandy marine soils and *T. pachydermus* generally occurs in sandy soils (73).

Although the movement of *Trichodorus* species in soil has not been reported previously, migration through the soil is a requirement for feeding and any inhibition of that movement will be reflected in the population dynamics of the species (83). The fact that nematodes are attracted by, and accumulate around, plant roots has led to two hypotheses to explain the phenomenon. The first supposes that nematodes move at random in the vicinity of plant roots, reaching a root by chance and that they remain there because of attraction near the root surface (66). The second hypothesis explains attraction in terms of the orientation of nematodes in concentration gradients of some secretion of the root which acts at a distance (10, 55, 77, 81, 82).

In conjunction with CRS, *Trichodorus* is normally found in low populations in potato fields, in many cases less than one nematode per liter of soil (28).

In 1961, Walkinshaw, Griffin and Larson (78) demonstrated that *T. christiei* is a vector of an American strain of TRV. In the same year, Sol and Seinhorst (70) reported *T. pachydermus* to be a vector of the Dutch strain of TRV. These were the first reports that TRV was nematode-transmitted and that species of *Trichodorus* could serve as virus vectors. The present list of *Trichodorus* vectors of TRV includes 11 species, three of which transmit American strains.

All juvenile and adult stages of *Trichodorus* have been shown to transmit TRV, except the first-stage juvenile, which is found within the egg (6). The virus is not transmitted through eggs or retained through molts (6).

The acquisition access threshold for several *Trichodorus* species is about one hour, with increases in the acquisition access period resulting in proportionate increases in the frequency of transmission (6).

The inoculation access threshold for *T. allius* was reported by Ayala (6) as one hour, with efficiency increasing as feeding time increased up to 24 hours.

Trichodorus species maintained in the absence of host plants may retain infective virus for periods which exceed the in vitro longevity of the virus in plant sap. Ayala (6) reported that *T. allius* transmitted TRV after 20 weeks without a host, and after 27 weeks when fed on virus-immune sweet pea. Van Hoof (37) reported retention of the Dutch strain of TRV by *T. pachydermus* for a period of three years in the absence of host plants.

The specificity of transmission of different geographical isolates of TRV by different species of *Trichodorus* has been reported by several authors (6, 36, 38), who found that more than one *Trichodorus* species can transmit a specific TRV isolate, but that each *Trichodorus* species can transmit only a few closely-related TRV isolates.

The Virus: Tobacco Rattle Virus (TRV) Quanjer, 1943

Tobacco rattle virus is an RNA-containing (Ribonucleic Acid) virus with straight tubular particles of two predominant lengths. The longer particle is 190 nm and the shorter one 45 to 115 nm, depending on the virus isolate (30). The host range of TRV is very wide; more than 400 species in over 50 dicotyledenous and monocotyledenous families can be infected (29). Specific isolates of the virus cause corky ringspot and stem-mottle in potato, notched leaf in *Gladiolus,* ringspot in aster and pepper, yellow blotch in sugar beet, early browning in pea and unnamed diseases in lettuce, hyacinth, narcissus, tulip and several other ornamental species (29).

Tobacco rattle virus (aster ringspot) has been found to be widespread in pepper and several other plants in central Florida (2, 3, 4) and in potatoes in the Hastings, Florida area (79, 80).

Several descriptions of the Hastings, Florida isolate of TRV have been published (30, 79, 80). The following is a compliation of the data presented in those descriptions.

Corky ringspot occurs in most of the potato-growing areas of Hastings, where the soil is a fine sand. The occurrence of the disease in a given area of in a given year is erratic, the incidence apparently being higher in areas of higher soil moisture. Examination of weeds from Hastings potato fields has revealed that two weed species, *Amaranthus retroflexus* L. (rough pigweed) and *Sonchus asper* (L.) Hill (sowthistle) are common hosts of TRV (80).

Walkinshaw and Larson (80) purified the Hastings isolate of TRV by freezing it in tobacco sap at -5 C overnight, thawing and subjecting it to low- and high-speed centrifugation, and resuspending it in potassium phosphate buffer (0.05M, pH 7.0).

In sap of *Nicotiana tabacum* L. 'Samsun', the thermal inactivation point of Hastings TRV is 90 C for 10 minutes; the dilution end-point is 10^{-4}; and infectivity is retained for 135 days at 20 C (80). The rod-shaped particles are of two sizes: 81 X 25 nm and 195 X 25 nm (30). The proportion of long particles to short particles is usually about 1:2.5 (30). Sedimentation coefficients are 200 and 296 (30). Precipitation with 50% ammonium sulfate does not decrease infectivity of the virus (79).

The only known vector of the Hastings isolate of TRV is the nematode *Trichodorus christiei* (78). Hastings TRV has been artificially transmitted by sap inoculation, bud grafting, stem grafting and "approach" grafting (79,80). Sap transmissibility of TRV from infected tubers decreases rapidly after harvest, with little or no transmission occurring after four to six weeks. Progeny plants grown from CRS-affected tubers are commonly infected with TRV (80).

The host range of Hastings TRV includes more than 50 species in 12 families of plants (30, 80).

Close serological relationships have been established between the Hastings isolate of TRV and isolates from Oregon and California (30). Very distant relationships were established with two Dutch isolates (79) and with a Brazilian isolate (30). No serological reactions were observed with four isolates from England and one isolate from Scotland (30).

With several isolates of TRV, some important features have been revealed which may be applicable to the Hastings isolate. These features were reviewed by Lister (46) and are summarized as follows.

A). Infection leads to the production of either stable or unstable forms of TRV. The infectivity of the stable form, but not the unstable form, is retained in host plant sap.

B). Stable forms, but not unstable forms, are antigenic and preparations made from them contain large numbers of tubular nucleoprotein particles of two predominant lengths. The "long" particles are about 190 nm long and the "short" particles are 45 to 115 nm long, depending on the virus isolate. When only short rods are placed into an indicator plant, there is no infection. When only long rods are used, lesions are produced but the virus attains only very low titers in the host. When both short and long particles are used, lesions are produced and the virus attains high titers.

C). Subculturing stable forms on local lesion hosts (though initially easy using either sap extracts or purified preparations) leads to the formation not only of lesions containing stable forms, but also some containing unstable forms which are difficult to transmit. This is especially true when dilute inocula are used.

D). Subculturing unstable forms is difficult even from systemic infections unless special methods such as phenol extraction are used. Phenol extracts are often highly infectious, suggesting that plants infected with unstable forms can contain much infective RNA. This RNA, being unprotected by virus protein, presumably becomes exposed to enzymic degradation in ordinary water or buffer extracts but not in phenol extracts.

E). Inoculating systemic hosts with preparations containing short particles together with phenol extracts from unstable-form infections results in the production of stable forms similar to those from which the unstable forms were originally derived.

Control of Potato Corky Ringspot Disease

Because both TRV and *Trichodorus* have very wide host ranges, including many weeds, and because *Trichodorus* species are known to retain TRV for long periods of time, crop rotation has not provided adequate control of CRS. The best prospects of control seem to be by using TRV-resistant or tolerant potato cultivars, or by controlling the nematode vector of the virus. Although some cultivars are resistant to TRV infection, and others tolerant of it (22), commercial considerations may necessitate growing those that are susceptible to infection. Under these circumstances control of the vector may be of most value.

Populations of *Trichodorus* can be reduced significantly by using available nematicides; however, rapid recovery of populations has been reported for *T. christiei* (35, 56). This has been attributed to the short life cycle and the high rate of egg production of this species, the abundance of healthy roots produced by plants grown in treated soil, and the elimination of natural enemies (56).

Christie (15) indicated that fallow or fallow and dry tillage may be fairly effective in controlling *T. christiei* but that flooding is not very effective.

Purpose of this Study

This research program was initiated to attempt to elucidate some biological and ecological relationships involved in the corky ringspot disease of potato in Hastings, Florida.

MATERIALS AND METHODS

Population Dynamics of *Trichodorus christiei* and *T. proximus* in a Potato Field

Soil samples were collected every two weeks from 2 March 1974 to 15 February 1975, from a plot of land measuring 198 m long by 9.8 m wide and designated as Bed Four, Yelvington farm (new land), ARC Hastings, Florida Agricultural Experiment Stations (Fig. 1, 2), near Hastings, Florida. Thirty random soil cores (10 cm diameter) were collected to a depth of 150 cm. Each core was divided into 10-cm sections, the 30 sections from a given depth mixed thoroughly and a 100 cc aliquant removed. Nematodes were extracted from the 100 cc aliquants by centrifugal-flotation (13) and specimens of *T. christiei* and *T. proximus* in each sample were counted. Potatoes were grown from 2 March 1974 to 8 June 1974, and weeds and a sorghum x sudangrass hybrid, cultivar 'Growfast', from 8 June 1974 to 15 February 1975. Correlation coefficients of depth, pH, soil moisture, water table level, sampling date and crop with nematode populations were calculated by using the square root transformation in an analysis of variance. Methods for soil analyses are given under "Determination of Soil Properties" below.

Nematode Inoculum

Trichodorus christiei and *T. proximus* used in all laboratory tests were obtained from the plot described above. All nematode inocula were obtained fresh from the field.

Figure 1. Bed Four, Yelvington farm (new land) during potato-growing season

Figure 2. Bed Four, Yelvington farm (new land) during cover-cropping season

Virus Inoculum

All potato tubers and shoots used as inoculum were obtained from the plot described above.

Soil Used in Laboratory Experiments

Soil used in all laboratory experiments was Rutlege fine sand collected from the plot described above. It was steam sterilized before use.

Laboratory Procedures for Plant Maintenance

Plants used in laboratory experiments were placed in a growth room 20 ± 1 C where they received 2421 lux of Gro-Lux® light for 16 hours of each 24-hour cycle. Plants were watered daily with distilled water and were fertilized weekly with 100 ml of Rapid-Gro® fertilizer solution (5 g/liter). Rapid-Gro® contains 23% total nitrogen, 19% phosphoric acid and 17% potash.

Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers Tomato, Sebago Potato and Pungo Potato

Seeds of tomato, *Lycopersicon esculentum* Mill. 'Rutgers' and seed pieces of potato, *Solanum tuberosum* L. 'Sebago' and 'Pungo' were planted in 15-cm clay pots containing sterile soil. Forty days after planting, six pots of each plant were inoculated with 500 adult *T. christiei*, six pots of each with 500 adult *T. proximus* and six were left as uninoculated controls.

Seventy-five days after inoculation, nematodes were extracted from the soil in each pot by centrifugal-flotation (13) and were counted. Height of plant above the soil line, top weight and root weight were recorded. Results were analyzed with a Student's t test.

Vertical Distribution of *Trichodorus christiei* and *T. proximus* in PVC Columns

Polyvinyl chloride (PVC) columns (10 X 175 cm) (Fig. 3) were filled with sterile Rutlege fine sand (screened through a 60-mesh sieve to remove debris) and each was planted with a 40-day-old Rutgers tomato seedling and inoculated with either 500 adult *T. christiei* or *T. proximus*. Water tables were maintained at 100, 125 and 150 cm below the soil surface. To establish water table levels, water as needed was added through the clear tubing connected to the bottom of the PVC columns. Six replicates at each water table level were inoculated at the top of the column and six at the bottom. Nematodes were introduced through the water used to establish the water table level for those columns inoculated at the bottom. For those inoculated at the top, the nematodes were placed in depressions made in the soil, covered with soil and watered lightly.

After 75 days, to remove the soil in 10 cm sections without disturbing it, the PVC pipe was laid down and cut lengthwise down two sides, the top piece lifted off and the soil removed carefully in 10 cm sections. The nematodes were extracted from each entire soil section by centrifugal-flotation (13) and counted to determine the number of nematodes at each depth. Results were analyzed by the square root transformation in an analysis of variance.

Effects of Soil Moisture on Survival and Reproduction of *Trichodorus christiei* and *T. proximus*

Constant-moisture funnels (Fig. 4, 5) (42) were filled with 400 g of sterile Rutlege fine sand and moisture levels adjusted to 0, 10, 20, 30 or 40% by weight. Each funnel was planted with a 21-day-old Rutgers tomato seedling, inoculated with 100 adult *T. christiei* or *T. proximus* and then enclosed in a plastic bag to maintain a constant soil moisture

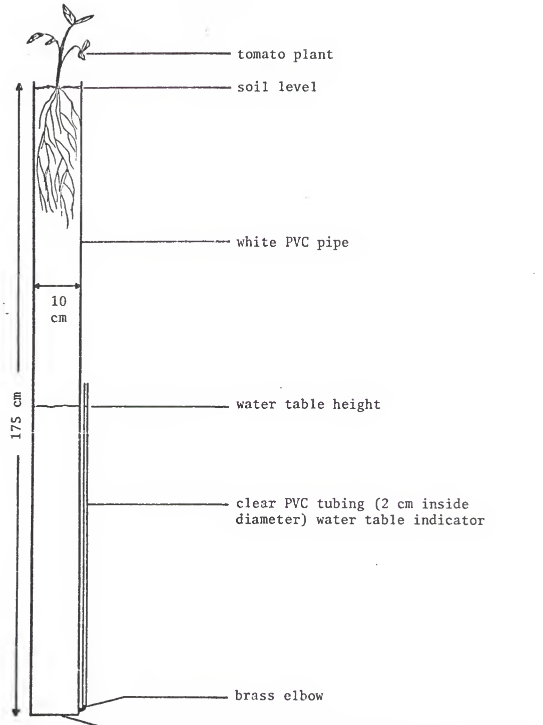

tomato plant
soil level
white PVC pipe
10 cm
175 cm
water table height
clear PVC tubing (2 cm inside diameter) water table indicator
brass elbow
plastic petri dish used to seal bottom

Figure 3. PVC column used in determining vertical distribution of *Trichodorus christiei* and *T. proximus*

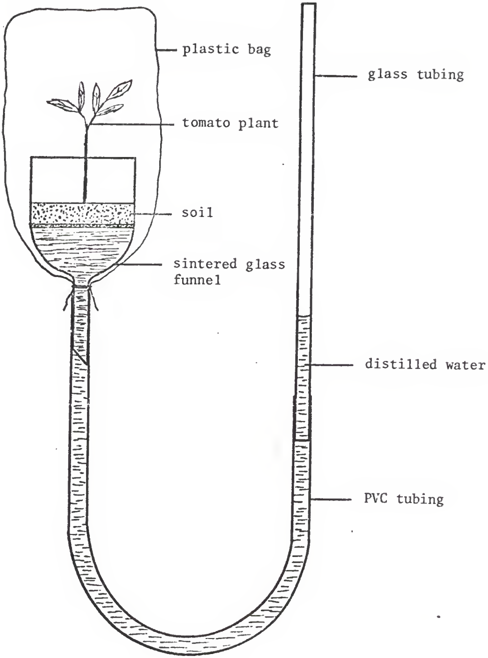


Figure 4. Constant-moisture funnel design (after Kable, Zehr and Mai, 1966)

Figure 5. Constant-moisture funnels in operation

Figure 6. Nematode horizontal movement box

level. Each moisture level and each nematode species was replicated six times. The funnels were placed in a growth room at 20 ± 1 C where they received 3228 lux of Gro-Lux light for 16 hours of each 24-hour cycle. After 37 days, the tomato plants, which had grown too large for the funnels, were cut off at the soil line, the funnels replanted with healthy 21-day-old Rutgers tomato seedlings, and resealed. Seventy-five days after inoculation (38 days after replanting), nematodes were extracted by centrifugal-flotation (13) from the entire volume of soil in each funnel and counted. Results were analyzed with a Student's t test.

Effects of Soil Collected at Different Depths on Survival and Reproduction of *Trichodorus christiei* and *T. proximus*

Soil cores were collected to a depth of 150 cm from Bed Four, Yelvington farm. Each core was divided into 10-cm sections, corresponing to the 10-cm sections used in the field population dynamics study described above. Soil from each depth was placed in 15-cm clay pots and each pot was planted with a 40-day old Rutgers tomato seedling and inoculated with 500 adults of either *T. christiei* or *T. proximus*. Each test was replicated six times. Seventy-five days after inoculation, nematodes were extracted from the entire volume of soil in each pot by centrifugal-flotation (13) and counted. Results were analyzed with a Student's t test.

Movement of *Trichodorus christiei* and *T. proximus* Through Soil

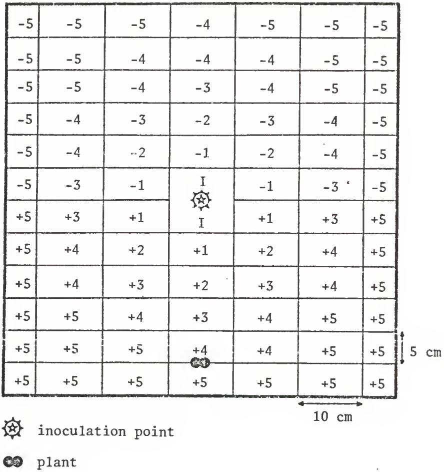
Sixteen liters of sifted Rutlege fine sand at a moisture content of 20% by weight were placed into a black-painted plexiglass box (60 X 60 x 5 cm) (Fig. 6). A 21-day-old Rutgers tomato seedling was planted 5 cm from the front of the box and 30 cm from each side. The top of the box was sealed with polyethylene plastic. Distilled water was dripped onto the root zone of the plant at a rate of about one drop each five seconds for 36 hours. Then the water source was removed and, through a hypodermic syringe, 2000 *T. christiei* or *T. proximus* were placed into the soil at the center of the box. After 72 hours in one test series and 36 hours in another test series, the soil was divided into 5 X 10 cm sections (Fig. 7), each section was removed from the box and nematodes were extracted by centrifugal-flotation (13) and counted. Each nematode species-elapsed time treatment was repeated six times.

Determination of Soil Properties

Soil pH and moisture content were determined on each biweekly set of samples collected for the population dynamics study described above. Bulk density, particle density, porosity, organic matter content and texture determinations were conducted with soil from the last collection (15 February 1975) of the population dynamics study.

Soil pH. Soil pH was measured by the method of Black et al. (9) as follows: 20 ml of distilled water was added to 20 g of soil in a 50 ml beaker. The resulting suspension was stirred several times during the next 30 minutes, then allowed to set undisturbed for one hour. The pH of the suspension then was measured with a Beckman Zeromatic II pH meter. The pH of six aliquants from each sample was determined.

Soil moisture content. The procedure for determining soil moisture content was adopted from Black et al. (9). Samples of 1 to 100 g of soil were placed in a pre-weighed, labeled aluminum weighing dishes and weighed immediately so that evaporation was negligible. Then the samples were placed in a drying oven at 110 C for a minimum of 24 hours, removed from the oven and placed in a desiccator containing active calcium sulfate desiccant until cooled to room temperature. The samples



-5	-5	-5	-4	-5	-5	-5
-5	-5	-4	-4	-4	-5	-5
-5	-5	-4	-3	-4	-5	-5
-5	-4	-3	-2	-3	-4	-5
-5	-4	-2	-1	-2	-4	-5
-5	-3	-1	I	-1	-3	-5
+5	+3	+1	I	+1	+3	+5
+5	+4	+2	+1	+2	+4	+5
+5	+4	+3	+2	+3	+4	+5
+5	+5	+4	+3	+4	+5	+5
+5	+5	+5	+4	+4	+5	+5
+5	+5	+5	+5	+5	+5	+5

Figure 7. Recovery zones of *Trichodorus* spp. from horizontal movement box (The blocks numbered +1 through +5 represent zones of migration toward the plant, and those numbered -1 through -5 represent zones of migration away from the plant. These zones were used in the statistical analyses of results, and represented more or less concentric circles from the point of inoculation.)

were weighed again and the moisture content computed by the following formula:

$$\% \text{ moisture} = \frac{(\text{wt. of wet soil}) - (\text{wt. of dry soil})}{(\text{wt. of dry soil})} \times 100$$

The soil moisture content of six aliquants from each sample was determined

Soil bulk density. The core method (9) was used to determine the bulk density. A metal cylinder was driven into the soil and the soil sample removed and dried in a drying oven at 110 C for 48 hours. The sample then was cooled in a desiccator and weighed. Bulk density was determined by dividing the oven-dried weights by the field volume of the sample. Each determination was replicated six times.

Soil particle density. A pycnometer was employed in the particle density determination (9). A 250 ml pycnometer was weighed, about 25 g of air-dried soil was added and the apparatus weighed again. Then the pycnometer was about half filled with distilled water and the contents boiled for several minutes while the apparatus was agitated gently. Then it was cooled to room temperature, enough boiled, cooled distilled water added to completely fill it, a stopper inserted and weighed again. The contents of the pycnometer were discarded and, after washing it thoroughly, it was filled with boiled, cooled distilled water and weighed as before, with the stopper inserted. Particle density was calculated as follows:

$$D_p = \frac{dw\ (W_s - W_a)}{(W_s - W_a) - (W_{sw} - W_w)}$$

D_p = particle density

d_w = density of water in g/cc at room temperature

W_a = weight of empty pycnometer

W_s = weight of pycnometer with soil

W_{sw} = weight of pycnometer filled with soil and water

W_w = weight of pycnometer filled with water

Each determination was replicated six times.

Soil porosity. Soil porosity was calculated by the following equation (9), using the data from the previous two determinations:

$$S_t = \frac{100\ D_p - D_b}{D_p}$$

S_t = total porosity

D_p = particle density

D_b = bulk density

Soil organic matter content. The Walkley-Black method of determination (9) was used to give an estimate of organic matter excluding mineral forms, suxh as $CaCO_3$ and $MgCO_3 \cdot CaCO_3$, and highly condensed, nearly elemental organic carbon. A 0.5 g sample os foil, previously passed through a 0.2 mm brass sieve, was placed in a 500 ml Erlenmeyer flask. Ten milliliters of 1 N $K_2Cr_2O_7$ solution were pipetted onto the soil and the two were mixed. Approximately 20 ml of concentrated H_2SO_4 were added and mixed by gentle swirling for one minute. A standardization blank was run in the same way (without soil). After 20 to 30 minutes, the solution was diluted to 200 ml with distilled water and 10 ml of 85% H_3PO_4, 0.2 g of NaF and 30 drops of diphenylamine indicator were added. The solution was titrated with $FeSO_4$ solution until the color turned from blue to green at the end point. Results were calculated by the following equation:

$$\%OM = 10(1 - \frac{T}{S}) \times f \times 1.33$$

%OM = percent organic matter

S = standardization blank titration (ml $FeSO_4$ solution used)

T = sample titration (ml $FeSO_4$ solution used)

f = 0.00669 x 100/g sample (0.00669 represents a constant)

Each determination was replicated six times.

Soil texture. The Bouyoucos hydrometer method (6) was used to determine soil texture. A 100 g sample of air-dried soil was placed in a dispersion cup. The cup then was filled with approximately 400 ml of distilled water and 100 ml of sodium hexametaphosphate solution (50 g/liter). The sample was left to soak for 15 to 20 hours, after which the dispersion cup was connected to a stirring motor and stirred for two minutes. The contents of the cup then were washed into a one liter graduated cylinder. The cylinder was filled to a one liter volume with distilled water and inverted several times to agitate the contents thoroughly. The cylinder was placed on a lab bench and a hydrometer placed in the suspension, steadied, read at the end of 40 seconds and removed slowly. After one hour and again after two hours, the hydrometer was inserted again, read and removed. A blank was prepared using the same amount of sodium hexametaphosphate in one liter of distilled water. Hydrometer readings were recorded to correct for temperature and the increase in density due to the dispersing agent. This was the hydrometer correction. The soil texture was calculated by the following equations:

at 40 seconds:

$$\frac{\text{corrected hydrometer reading}}{\text{dry weight of soil}} \times 100 = \%(\text{coarse silt} + \text{fine silt} + \text{clay})$$

at one hour:

$$\frac{\text{corrected hydrometer reading}}{\text{dry weight of soil}} \times 100 = \%(\text{fine silt} + \text{clay})$$

at 2 hours:

$$\frac{\text{corrected hydrometer reading}}{\text{dry weight of soil}} \times 100 = \%\ \text{clay}$$

$\%\ \text{sand} = 100 - \%(\text{coarse silt} + \text{fine silt} + \text{clay})$

$\%\ \text{coarse silt} = \%(\text{coarse silt} + \text{fine silt} + \text{clay}) - \%(\text{fine silt} + \text{clay})$

$\%\ \text{fine silt} = \%(\text{fine silt} + \text{clay}) - \%\ \text{clay}$

Isolation of Tobacco Rattle Virus

Transmission of TRV from corky ringspot-affected potatoes. Expressed sap of triturated tissues from corky ringspot-affected Sebago potato tubers and from sprouts grown from corky ringspot-affected Sebago potato tubers was rubbed on carborundum-dusted leaves of test plants using sterile gauze pads. Phosphate buffer (0.05M, pH 7.3) was used as a diluent.

Transmission of TRV from test plants inoculated with expressed sap from corky ringspot-affected potatoes. Expressed sap from triturated leaves of test plants inoculated with the expressed sap from CRS-affected Sebago potato tubers was rubbed on carborundum-dusted leaves of test plants using sterile gauze pads. Phosphate buffer (0.05M, pH 7.3) was used as a diluent.

Tests for transmission of TRV by nematodes. Nematodes used in transmission experiments were extracted from soil collected from locations having high incidence of CRS. Nematodes were extracted by centrifugal-flotation (13), and mature adult *T. christiei* and *T. proximus* were transferred to separate watchglasses containing distilled water. The nematodes were transferred immediately to 15-cm clay pots containing sterile soil and either one 21-day-old cucumber seedling (*Cucumis sativus* L. 'Chicago Pickling') or one 60-day-old tobacco seedling (*Nicotiana tabacum* 'Samsun NN'). Twenty-eight days after inoculation, roots and leaves of bait plants were triturated in 0.05M phosphate buffer (pH 7.3) and the sap was rubbed on carborundum-dusted leaves of healthy Samsun NN tobacco plants using sterile gauze pads. The appearance of necrotic local lesions on these plants was considered evidence for the transmission of TRV to bait plants by the nematodes. After removal of bait plants, the nematode population level in each pot was checked.

Electron microscopy. Tissue dips (51) in 2% potassium phosphotungstate (pH 6.8) were examined with a Philips 200 electron microscope.

Phenol extracts of corky ringspot-affected potato tissues. Weighed amounts (about 20 g) of Sebago potato tissues were mixed with 30 ml of pH 9.0 buffer (0.05M boric acid; 0.01M KCl; 0.001M EDTA), 50 ml of phenol, 8 ml of 10% SDS, and 2.5 ml of Bentonite (10 mg/ml). The mixture was placed in an ice bath, homogenized for 45 seconds, and emulsified for four minutes, fifteen seconds. The slurry was centrifuged for five minutes at 7000 rpm at 1 C. To the supernatant was added an equal amount of cold phenol. This mixture then was emulsified in a blender for four minutes and centrifuged for five minutes at 7000 rpm at 1 C. To the supernatant was added 95% ethyl alcohol containing sodium acetate (0.15M, pH 5.5). The mixture was cooled to -20 C, then centrifuged for 20 minutes at 15,000 rpm at 1 C. The pellet from this centrifugation was resuspended in pH 7.0 SSC (0.15M NaCl; 0.015M sodium citrate) and centrifuged 10 minutes at 10,000 rpm at 1 C. The ethanol precipitation then was repeated. The preparations, diluted with an equal amount of pH 9.2 buffer (0.035M K_2HPO_4; 0.05M glycine; 100 mg/ml Bentonite), and mixed with 'Celite' abrasive powder, were assayed for infectivity by manual inoculation to leaves of test plants.

RESULTS

Population Dynamics of *Trichodorus christiei* and *T. proximus* in a Potato Field

Seasonal population fluctuations of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land) are represented in Figures 8 and 9. Population levels of both species remained relatively stable during the sampling period (Table 1), and, although both species exhibited population peaks at several times during the year, there were no statistically significant variations among the 26 biweekly sampling dates for either species.

In comparing populations recovered during the potato cropping season (2 March 1974 to 8 June 1974) with those recovered during cover cropping (8 June 1974 to 15 February 1975), the number of female *T. christiei* was significantly ($P>0.05$) higher on potato than on the sorghum and weed cover crop. No significant differences between the two crops were found for juveniles and gravid females of *T. christiei* nor for any life cycle stage of *T. proximus*.

Populations of both *T. christiei* and *T. proximus* were highly negatively correlated ($P>0.01$) with depth in the soil (Table 2; Fig. 10). Highest densities of *T. christiei* occurred at 10 to 40 cm and of *T. proximus* at 20 to 50 cm (Table 1). Soil moisture at 10 to 50 cm ranged from 20 to 29% by weight. No nematodes were found below the water table, which varied from 50 to 180 cm from the surface during the sampling period.

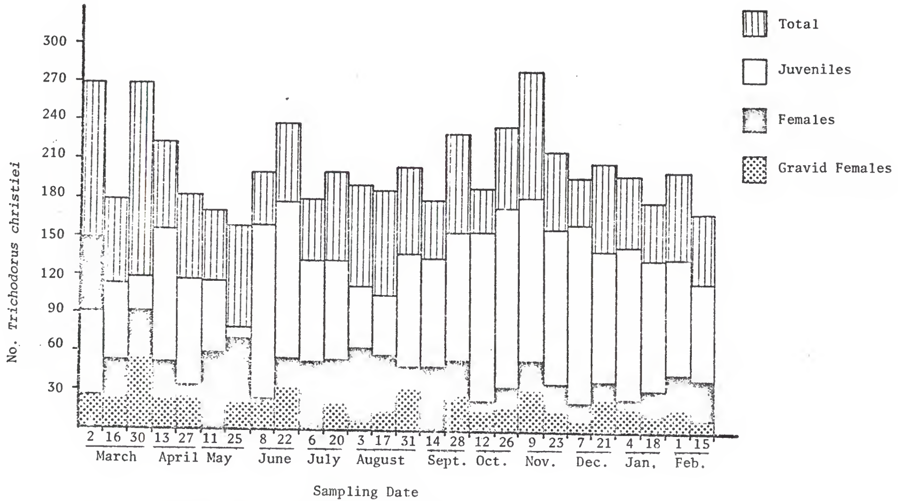


Figure 8. Seasonal population fluctuations of *Trichodorus christiei* in a potato field (Bed Four, Yelvington farm, ARC Hastings, Florida)

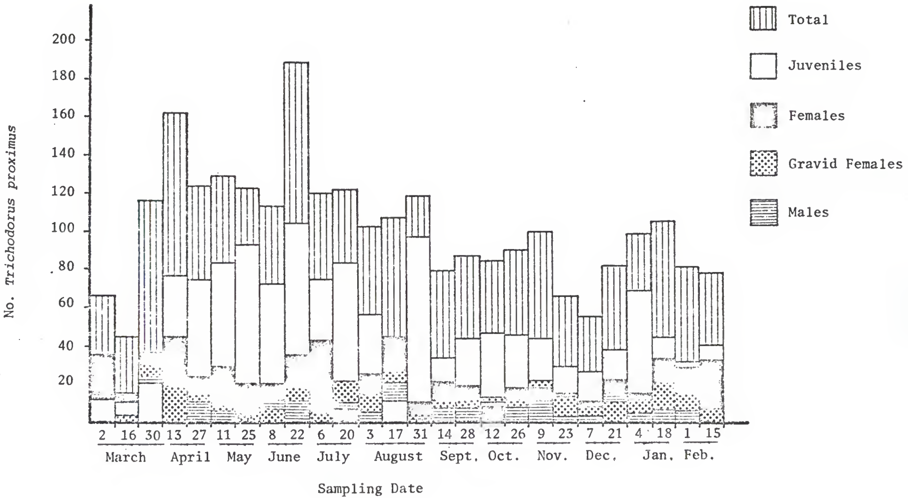


Figure 9. Seasonal population fluctuations of *Trichodorus proximus* in a potato field (Bed Four, Yelvington farm, ARC Hastings, Florida)

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida.

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
2 III 74	0-10	4	0	7	0	11	0	0	0	0	0
	10-20	18	0	25	4	47	0	4	0	0	4
	20-30	11	0	35	4	50	0	0	7	0	7
	30-40	18	0	42	11	71	0	7	7	0	14
	40-50	7	0	14	7	28	0	0	4	0	4
	50-60	7	0	0	0	7	4	0	11	0	15
	60-70	4	0	7	0	11	0	0	0	0	0
	70-80	4	0	11	0	15	0	4	0	0	4
	80-90	0	0	4	0	4	0	0	0	0	0
	90-100	4	0	0	0	4	7	0	4	0	11
	100-110	14	0	0	0	14	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	4	0	4
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	4	0	4	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	91	0	149	26	266	11	15	37	0	63

Water Table = 180 cm

Two-week accumulated rainfall = 3.66 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
16 III 74	0-10	11	0	7	0	18	0	0	0	0	0
	10-20	28	0	18	14	60	0	4	0	0	4
	20-30	21	0	7	4	32	0	4	7	0	11
	30-40	18	0	7	0	25	0	7	0	0	7
	40-50	0	0	0	0	0	0	0	4	0	4
	50-60	14	0	0	4	18	4	0	0	0	4
	60-70	4	0	7	0	11	0	0	0	4	4
	70-80	7	0	4	0	11	4	0	0	0	4
	80-90	4	0	0	0	4	4	0	0	0	4
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	107	0	50	22	179	12	15	11	4	42

Water Table = 160 cm

Two-week accumulated rainfall = 0.43 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
30 III 74	0-10	21	0	14	4	39	0	0	4	0	4
	10-20	18	0	11	7	36	0	4	0	0	4
	20-30	28	0	11	7	46	0	0	0	4	4
	30-40	11	0	25	4	40	7	0	4	4	15
	40-50	4	0	7	21	32	4	4	7	7	22
	50-60	7	0	4	4	15	0	4	4	4	12
	60-70	7	0	7	4	18	0	4	0	4	8
	70-80	4	0	4	0	8	11	4	0	4	19
	80-90	4	0	4	4	12	0	0	4	0	4
	90-100	0	0	4	0	4	0	0	7	4	11
	100-110	7	0	0	0	7	0	0	4	0	4
	110-120	4	0	0	0	4	4	0	4	0	8
	120-130	4	0	0	0	4	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	119	0	91	55	265	26	20	38	31	115

Water Table = 130 cm

Two-week accumulated rainfall = 10.97 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farms (new land), ARC Hastings, Florida. (cont'd)

Sampling Date	Soil Depth	*Trichodorus christiei* Juveniles	Males	Females	Gravid Females	Total	*Trichodorus proximus* Juveniles	Males	Females	Gravid Females	Total
13 IV 74	0-10	21	0	0	0	21	7	0	0	0	7
	10-20	28	0	4	0	32	11	0	0	0	11
	20-30	53	0	11	4	68	11	0	11	0	22
	30-40	21	0	7	7	35	28	4	7	4	43
	40-50	11	0	11	7	29	4	4	4	4	16
	50-60	7	0	7	4	18	4	4	4	0	12
	60-70	7	0	4	0	11	7	4	4	0	15
	70-80	4	0	4	0	8	4	4	0	7	15
	80-90	0	0	0	0	0	0	0	7	4	11
	90-100	0	0	0	0	0	0	0	4	0	4
	100-110	4	0	0	0	4	0	0	4	0	4
	110-120	4	0	0	0	4	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	160	0	48	22	230	76	20	45	19	160

Water Table = 120 cm

Two-week accumulated rainfall = 0.66 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
27 IV 74	0-10	18	0	7	0	25	0	0	0	0	0
	10-20	11	0	7	0	18	0	0	4	0	4
	20-30	21	0	11	4	36	0	0	0	0	0
	30-40	14	0	4	7	25	11	7	7	4	29
	40-50	14	0	0	7	21	11	4	4	4	23
	50-60	11	0	4	7	22	21	0	4	0	25
	60-70	11	0	4	0	15	14	0	0	0	14
	70-80	7	0	4	0	11	7	0	0	0	7
	80-90	4	0	0	0	4	0	0	4	4	8
	90-100	4	0	0	0	4	4	0	0	0	4
	100-110	0	0	0	0	0	4	0	0	4	8
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	115	0	41	25	181	72	11	23	16	122

Water Table = 100 cm

Two-week accumulated rainfall = 1.07 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
11 V 74	0-10	0	0	4	0	4	0	0	0	0	0
	10-20	7	0	4	0	11	0	0	0	0	0
	20-30	14	0	0	0	14	0	7	14	0	21
	30-40	14	0	14	0	28	0	0	4	0	4
	40-50	21	0	7	0	28	14	0	0	4	18
	50-60	11	0	11	0	22	14	0	7	4	25
	60-70	14	0	7	0	21	7	0	4	0	11
	70-80	7	0	7	0	14	4	0	0	0	4
	80-90	0	0	4	0	4	7	0	0	0	7
	90-100	7	0	0	0	7	14	0	0	0	14
	100-110	4	0	0	0	4	11	0	0	0	11
	110-120	7	0	0	0	7	7	0	0	0	7
	120-130	4	0	4	0	8	7	0	0	0	7
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	4	0	0	0	4	0	0	0	0	0
	Totals	114	0	62	0	176	85	7	29	8	129

Water Table = 130 cm

Two-week accumulated rainfall = 2.41 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
25 V 74	0-10	7	0	14	0	21	18	0	7	4	29
	10-20	7	0	21	0	28	63	4	7	0	74
	20-30	11	0	11	14	36	4	0	7	0	11
	30-40	7	0	7	7	21	7	0	0	0	7
	40-50	4	0	4	0	8	0	0	0	0	0
	50-60	0	0	7	0	7	0	0	0	0	0
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	4	0	0	0	4	0	0	0	0	0
	90-100	4	0	0	0	4	0	0	0	0	0
	100-110	4	0	0	0	4	0	0	0	0	0
	110-120	7	0	0	0	7	0	0	0	0	0
	120-130	4	0	0	0	4	0	0	0	0	0
	130-140	4	0	0	0	4	0	0	0	0	0
	140-150	11	0	0	0	11	0	0	0	0	0
	Totals	74	0	64	21	159	92	4	21	4	121

Water Table = 140 cm

Two-week accumulated rainfall = 6.07 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
8 VI 74	0-10	53	0	4	0	57	7	0	0	0	7
	10-20	60	0	11	14	85	25	4	0	0	29
	20-30	21	0	4	7	32	25	7	21	7	60
	30-40	18	0	4	0	22	4	0	0	0	4
	40-50	7	0	0	0	7	7	0	0	0	7
	50-60	0	0	0	0	0	4	0	0	0	4
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	159	0	23	21	203	72	11	21	7	111

Water Table = 130 cm

Two-week accumulated rainfall = 2.59 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
22 VI 74	0-10	25	0	4	0	29	14	0	0	4	18
	10-20	91	0	18	14	123	35	7	7	7	56
	20-30	46	0	18	14	78	25	4	18	7	54
	30-40	11	0	11	7	29	14	0	4	0	18
	40-50	4	0	0	0	4	14	0	7	0	21
	50-60	0	0	0	0	0	7	0	0	0	7
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	177	0	51	35	263	109	11	36	18	174

Water Table = 110 cm

Two-week accumulated rainfall = 5.18 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
6 VII 74	0-10	74	0	21	0	95	0	0	11	0	11
	10-20	32	0	14	0	46	56	0	11	0	67
	20-30	4	0	14	0	18	14	0	4	4	22
	30-40	14	0	0	0	14	4	0	11	0	15
	40-50	7	0	0	0	7	0	0	7	0	7
	50-60	0	0	0	0	0	0	0	0	0	0
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	131	0	49	0	180	74	0	44	4	122

Water Table = 60 cm

Two-week accumulated rainfall = 24.13 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
20 VII 74	0-10	60	0	11	7	78	11	0	0	0	11
	10-20	49	0	21	11	81	28	4	0	0	32
	20-30	11	0	7	0	18	25	7	7	0	39
	30-40	11	0	7	4	22	4	0	0	11	15
	40-50	0	0	4	0	4	4	0	0	4	8
	50-60	0	0	0	0	0	11	0	0	7	18
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	131	0	50	22	203	83	11	7	22	123

Water Table = 60 cm

Two-week accumulated rainfall = 4.95 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
3VIII 74	0-10	28	0	49	0	77	4	0	0	0	4
	10-20	67	0	11	7	85	14	0	7	0	21
	20-30	14	0	14	0	28	42	14	18	4	78
	30-40	0	0	0	0	0	0	0	0	0	0
	40-50	0	0	0	0	0	0	0	0	0	0
	50-60	0	0	0	0	0	0	0	0	0	0
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	109	0	74	7	190	60	14	25	4	103

Water Table = 60 cm

Two-week accumulated rainfall = 9.91 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
17VIII 74	0-10	14	0	18	0	32	0	0	0	0	0
	10-20	46	0	25	11	82	0	4	14	7	25
	20-30	28	0	7	7	42	25	7	25	7	64
	30-40	14	0	4	0	18	0	0	0	7	7
	40-50	0	0	11	0	11	4	0	7	0	11
	50-60	0	0	0	0	0	0	0	0	0	0
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	102	0	65	18	185	29	11	46	21	107

Water Table = 80 cm

Two-week accumulated rainfall = 9.73 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
31 VIII 74	0-10	14	0	7	0	21	0	0	0	0	0
	10-20	60	0	28	21	109	42	0	0	0	42
	20-30	18	0	7	11	36	21	4	7	4	36
	30-40	18	0	4	0	22	18	0	4	0	22
	40-50	14	0	0	0	14	4	0	0	0	4
	50-60	11	0	0	0	11	4	0	0	0	4
	60-70	11	0	0	0	11	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	4	0	0	0	4
	100-110	0	0	0	0	0	7	0	0	0	7
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	146	0	46	32	224	100	4	11	4	119

Water Table = 90 cm

Two-week accumulated rainfall = 7.80 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
14 IX 74	0-10	11	0	7	0	18	0	0	0	0	0
	10-20	25	0	14	0	39	7	4	4	0	15
	20-30	39	0	14	0	53	7	4	18	11	40
	30-40	32	0	11	0	43	11	0	0	0	11
	40-50	28	0	0	0	28	14	0	0	0	14
	50-60	0	0	0	0	0	0	0	0	0	0
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	135	0	46	0	181	39	8	22	11	80

Water Table = 50 cm.

Two-week accumulated rainfall = 15.34 cm.

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
28 IX 74	0-10	14	0	0	0	14	0	0	0	0	0
	10-20	25	0	11	4	40	11	0	4	0	15
	20-30	18	0	11	4	33	7	4	4	0	15
	30-40	21	0	14	21	56	0	4	4	4	12
	40-50	46	0	7	0	53	11	0	7	7	25
	50-60	14	0	4	0	18	7	0	0	0	7
	60-70	18	0	4	0	22	14	0	0	0	14
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	156	0	51	29	236	50	8	19	11	88

Water Table = 70 cm.

Two-week accumulated rainfall = 6.82 cm.

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
12 X 74	0-10	0	0	0	0	0	0	0	0	0	0
	10-20	14	0	0	0	14	0	0	0	0	0
	20-30	28	0	0	4	32	11	0	0	4	15
	30-40	28	0	11	0	39	14	7	7	4	32
	40-50	25	0	14	11	50	7	4	0	4	15
	50-60	42	0	0	0	42	11	0	0	0	11
	60-70	11	0	0	0	11	11	0	0	0	11
	70-80	7	0	0	0	7	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	155	0	25	15	195	54	11	7	12	84

Water Table = 80 cm

Two-week accumulated rainfall = 5.35 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
26 X 74	0-10	39	0	11	7	57	11	0	0	0	11
	10-20	21	0	7	7	35	4	0	11	0	15
	20-30	28	0	7	4	39	18	4	7	7	36
	30-40	21	0	4	7	32	7	4	0	4	15
	40-50	35	0	7	0	42	4	0	0	0	4
	50-60	14	0	4	0	18	4	0	0	0	4
	60-70	11	0	0	0	11	0	0	0	0	0
	70-80	4	0	0	0	4	0	0	0	0	0
	80-90	0	0	0	0	0	4	0	0	0	4
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	173	0	40	25	238	52	8	18	11	89

Water Table = 90 cm.

Two-week accumulated rainfall = 7.48 cm.

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
9 XI 74	0-10	67	0	11	7	85	0	0	0	0	0
	10-20	39	0	18	28	85	14	0	0	0	14
	20-30	28	0	11	4	43	14	7	0	11	32
	30-40	18	0	14	0	32	7	14	18	0	39
	40-50	14	0	4	0	18	0	0	0	0	0
	50-60	7	0	0	0	7	7	0	0	0	7
	60-70	7	0	0	0	7	0	0	0	0	0
	70-80	0	0	0	0	0	4	0	0	0	4
	80-90	0	0	0	0	0	4	0	0	0	4
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	180	0	58	39	277	50	21	18	11	100

Water Table = 90 cm.

Two-week accumulated rainfall = 0.08 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
23 XI 74	0-10	14	0	4	0	18	0	0	0	0	0
	10-20	42	0	11	0	53	0	0	0	0	0
	20-30	18	0	11	0	29	4	0	0	0	4
	30-40	14	0	4	11	29	7	4	4	4	19
	40-50	25	0	7	7	39	7	0	4	4	15
	50-60	21	0	4	0	25	7	0	0	4	11
	60-70	11	0	0	0	11	4	0	0	0	4
	70-80	11	0	0	0	11	0	0	7	0	7
	80-90	4	0	0	0	4	4	0	0	0	4
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	160	0	41	18	219	33	4	15	12	64

Water Table = 90 cm

Two-week accumulated rainfall = 1.09 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
7 XII 74	0-10	11	0	4	0	15	0	0	0	0	0
	10-20	35	0	0	0	35	4	0	0	0	4
	20-30	25	0	4	7	36	7	4	4	0	15
	30-40	28	0	11	4	43	0	4	7	0	11
	40-50	28	0	0	0	28	0	0	0	0	0
	50-60	32	0	4	0	36	4	0	0	0	4
	60-70	4	0	0	0	4	0	0	0	0	0
	70-80	0	0	0	0	0	7	0	0	4	11
	80-90	0	0	0	0	0	7	0	0	0	7
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	163	0	23	11	197	29	8	11	4	52

Water Table = 100 cm

Two-week accumulated rainfall = 1.09 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
21 XII 74	0-10	18	0	11	7	36	7	0	0	0	7
	10-20	42	0	14	11	67	11	0	4	0	15
	20-30	32	0	7	7	46	11	0	14	7	32
	30-40	18	0	7	0	25	4	11	4	4	23
	40-50	14	0	4	0	18	4	0	0	4	8
	50-60	18	0	0	0	18	0	0	0	0	0
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	142	0	43	25	210	37	11	22	15	85

Water Table = 80 cm

Two-week accumulated rainfall = 3.35 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
4 I 75	0-10	28	0	4	0	32	7	0	4	0	11
	10-20	60	0	11	11	82	21	7	4	0	32
	20-30	32	0	11	4	47	21	0	7	4	32
	30-40	21	0	0	4	25	7	4	0	0	11
	40-50	4	0	0	0	4	0	0	0	0	0
	50-60	0	0	0	0	0	4	0	0	0	4
	60-70	0	0	0	0	0	4	0	0	0	4
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	4	0	0	0	4
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	145	0	26	19	190	68	11	15	4	98

Water Table = 80 cm

Two-week accumulated rainfall = 0.13 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
18 I 75	0-10	32	0	7	0	39	7	0	4	0	11
	10-20	28	0	7	0	35	18	14	11	7	50
	20-30	32	0	11	7	50	4	7	11	0	22
	30-40	18	0	4	4	26	7	0	7	0	14
	40-50	28	0	4	0	32	4	0	0	0	4
	50-60	0	0	0	0	0	0	0	0	0	0
	60-70	0	0	0	0	0	4	0	0	0	4
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	138	0	33	11	182	44	21	33	7	105

Water Table = 70 cm

Two-week accumulated rainfall = 4.88 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
1 II 75	0-10	11	0	0	0	11	0	0	4	0	4
	10-20	14	0	7	0	21	4	4	7	0	15
	20-30	67	0	28	11	106	21	11	18	7	57
	30-40	28	0	11	7	46	7	0	0	0	7
	40-50	7	0	0	0	7	0	0	0	0	0
	50-60	11	0	0	0	11	0	0	0	0	0
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	138	0	46	18	202	32	15	29	7	83

Water Table = 70 cm

Two-week accumulated rainfall = 2.31 cm

Table 1. Population densities of *Trichodorus christiei* and *T. proximus* recovered from Bed Four, Yelvington farm (new land), ARC Hastings, Florida. (cont'd)

		Trichodorus christiei					*Trichodorus proximus*				
Sampling Date	Soil Depth	Juveniles	Males	Females	Gravid Females	Total	Juveniles	Males	Females	Gravid Females	Total
15 II 75	0-10	21	0	7	0	28	0	0	0	0	0
	10-20	14	0	7	7	28	0	0	0	0	0
	20-30	32	0	21	0	53	11	7	4	0	22
	30-40	46	0	0	0	46	25	0	0	0	25
	40-50	4	0	4	0	8	0	0	7	0	7
	50-60	4	0	0	0	4	4	0	21	0	25
	60-70	0	0	0	0	0	0	0	0	0	0
	70-80	0	0	0	0	0	0	0	0	0	0
	80-90	0	0	0	0	0	0	0	0	0	0
	90-100	0	0	0	0	0	0	0	0	0	0
	100-110	0	0	0	0	0	0	0	0	0	0
	110-120	0	0	0	0	0	0	0	0	0	0
	120-130	0	0	0	0	0	0	0	0	0	0
	130-140	0	0	0	0	0	0	0	0	0	0
	140-150	0	0	0	0	0	0	0	0	0	0
	Totals	121	0	39	7	167	40	7	32	0	79

Water Table = 70 cm

Two-week accumulated rainfall = 6.68 cm

Table 2.

Correlation of Field Populations of *Trichodorus christiei* and *T. proximus* with Depth in the Soil: Correlation Coefficients / Prob 1R1 under HO: RHO = 0

Nematode Species	Total Nematodes	Juveniles	Males	Females	Gravid Females
T. christiei	-0.731454 0.0001	-0.712962 0.0001	0 0	-0.637947 0.0001	-0.401957 0.0001
T. proximus	-0.385987 0.0001	-0.307418 0.0001	-0.268780 0.0001	-0.339302 0.0001	-0.136351 0.0348

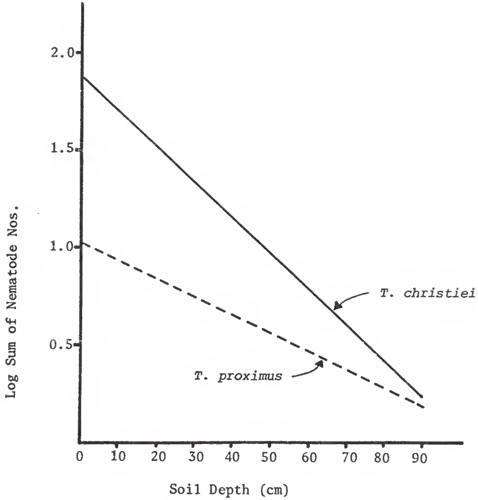


Figure 10. Correlation of *Trichodorus christiei* and *T. proximus* with soil depth

Populations of both species were negatively correlated (P>0.05) with soil moisture content (Table 3) which, in turn, was correlated (P>0.05) with rainfall. Only the juveniles of *T. christiei* showed a correlation (P>0.05) with soil pH (Table 4).

Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers Tomato, Sebago Potato and Pungo Potato

Both *T. christiei* and *T. proximus* caused significant (P>0.01) reductions in the fresh weights of tops and roots, but had no significant effects on the height of Rutgers tomato (Table 5; Fig. 11, 12). Top weights and root weights of Rutgers tomato plants fed upon by *T. proximus* were significantly (P>0.01) lower than those of plants fed upon by *T. christiei* (Table 5; Fig. 11, 12). Populations of *T. christiei* and *T. proximus* increased significantly (P>0.01) on tomato. Neither nematode influenced the heights or weights of either Sebago or Pungo potato (Table 5), and fewer nematodes were recovered from each cultivar than were used as inoculum (Table 5).

Vertical Distribution of *Trichodorus christiei* and *T. proximus* in PVC Columns

The vertical distribution of *T. christiei* and *T. proximus* in PVC columns is represented in Fgiures 13 through 18. Females and gravid females of *T. christiei* and all life cycle stages of *T. proximus* were negatively correlated (P>0.05) with soil depth (Tables 6, 7), and juveniles of *T. christiei* and all life cycle stages of *T. proximus* were correlated (P>0.05) with soil moisture. Highest densities of *T. christiei* occurred at 10 to 60 cm, and of *T. proximus* at 10 to 40 cm, where soil moisture was 10 to 17% by weight. In no case were nematodes of either species found below the water table. In comparing distribution of nematodes when introduced at the bottom of the column, no significant differrences occurred in vertical distribution, nor were greater numbers recovered from one treatment than the other.

Table 3.

Correlation of Field Populations of *Trichodorus christiei* and *T. proximus* with Soil Moisture:
Correlation Coefficients / Prob lRl under H0: RHO = 0

Nematode Species	Total Nematodes	Juveniles	Males	Females	Gravid Females
T. christiei	-0.433785	-0.434829	0	-0.298689	-0.241835
	0.0001	0.0001	0	0.0001	0.0004
T. proximus	-0.233755	-0.191430	-0.167308	-0.161393	-0.188943
	0.0006	0.0036	0.0101	0.0129	0.0040

Table 4.

Correlation of Field Populations of *Trichodorus christiei* and *T. proximus* with Soil pH: Correlation Coefficients / Prob 1R1 under HO: RHO = 0

Nematode Species	Total Nematodes	Juveniles	Males	Females	Gravid Females
T. christiei	-0.104474	-0.136823	0	-0.035844	-0.069201
	0.0569	0.0342	0	0.5927	0.2919
T. proximus	-0.025635	-0.014047	0.064925	-0.023166	-0.030507
	0.7963	0.8253	0.6765	0.7249	0.6476

Table 5.

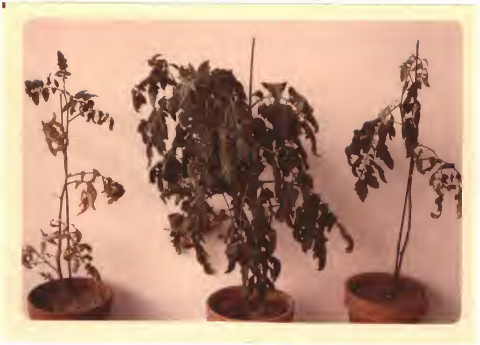
Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers tomato, Sebago potato and Pungo potato (mean of 6 replicates; 500 specimens used as inoculum)

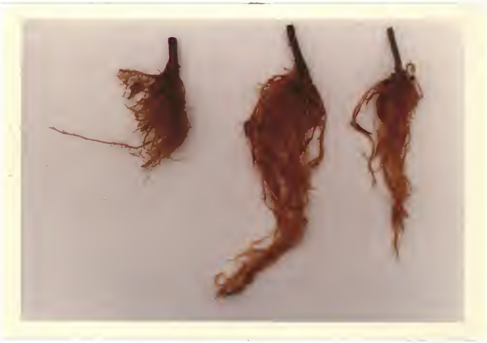
	Plant Height (cm)	Plant Weights (g)		Nematodes Recovered After 75 Days			
		Top	Roots	Juveniles	Males	Females	Gravid Females
Rutgers tomato							
T. christiei	64.0	44.0*	12.4*	2402	0	372	90
T. proximus	64.5	33.0*	10.8*	1393	37	524	32
Control	68.3	128.3	20.1	0	0	0	0
Sebago potato							
T. christiei	42.2	161.2	24.5	147	0	211	16
T. proximus	38.8	165.2	23.9	115	12	135	7
Control	43.0	171.3	24.4	0	0	0	0
Pungo potato							
T. christiei	48.9	171.3	24.9	169	0	181	16
T. proximus	54.3	158.6	25.0	120	13	146	7
Control	49.6	168.2	25.3	0	0	0	0

*P>0.01

Figure 11. Pathogenicity of *Trichodorus christiei* and *T. proximus* to Rutgers tomato (left: inoculated with 500 *T. christiei;* center: uninoculated control; right: inoculated with 500 *T. proximus)*

Figure 12. Damage to Rutgers tomato roots caused by *Trichodorus christiei* and *T. proximus* (left: inoculated with 500 *T. christiei;* center: uninoculated control; right: inoculated with 500 *T. proximus*)





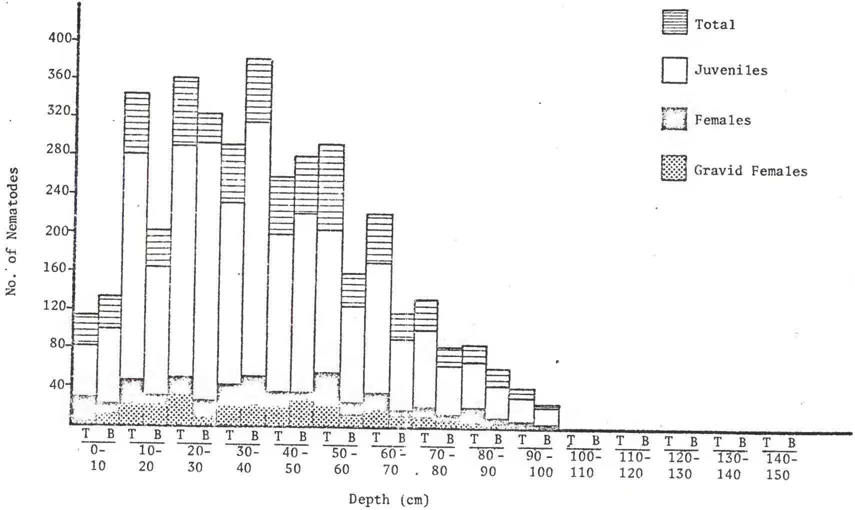


Figure 13. Mean vertical distribution of *Trichodorus christiei* in PVC columns with 1.0 m water tables (T=nematodes introduced at top of column; B=nematodes introduced at bottom of column)

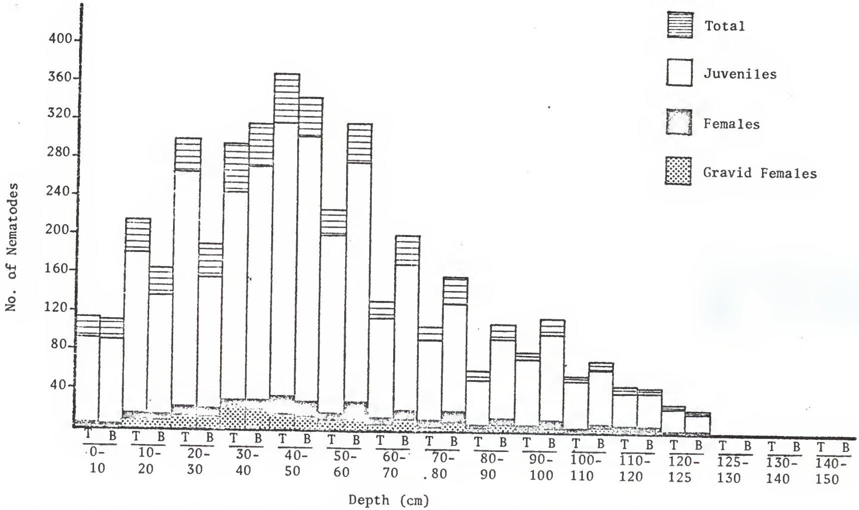


Figure 14. Mean vertical distribution of *Trichodorus christiei* in PVC columns with 1.25 m water tables (T=nematodes introduced at top of column; B=nematodes introduced at bottom of column)

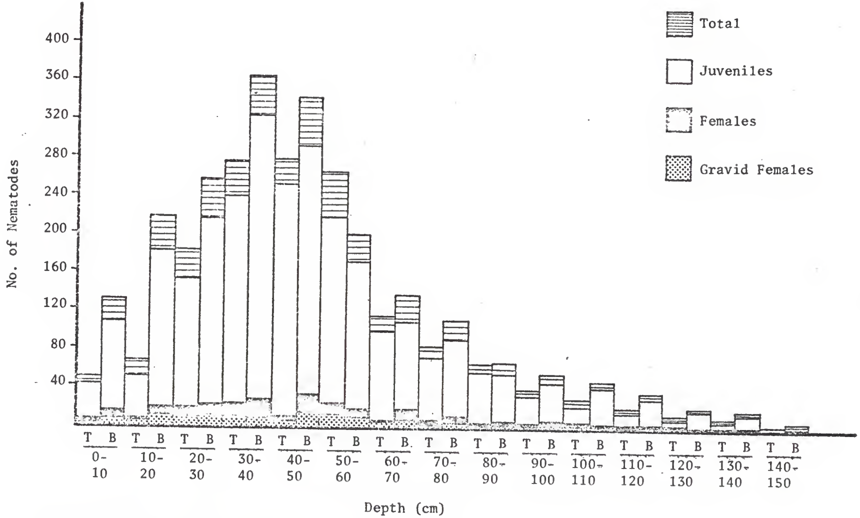


Figure 15. Mean vertical distribution of *Trichodorus christiei* in PVC columns with 1.5 m water tables (T=nematodes introduced at top of column: B=nematodes introduced at bottom of column)

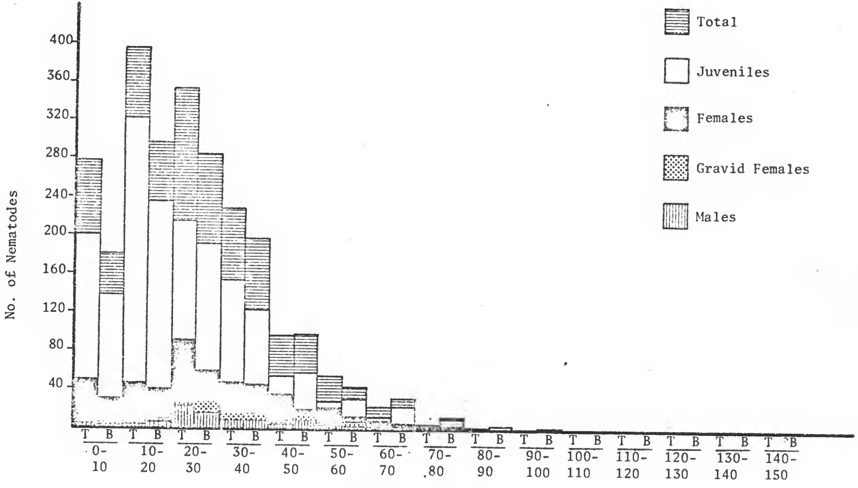


Figure 16. Mean vertical distribution of *Trichodorus proximus* in PVC columns with 1.0 m water tables (T=nematodes introduced at top of column; B=nematodes introduced at bottom of column)

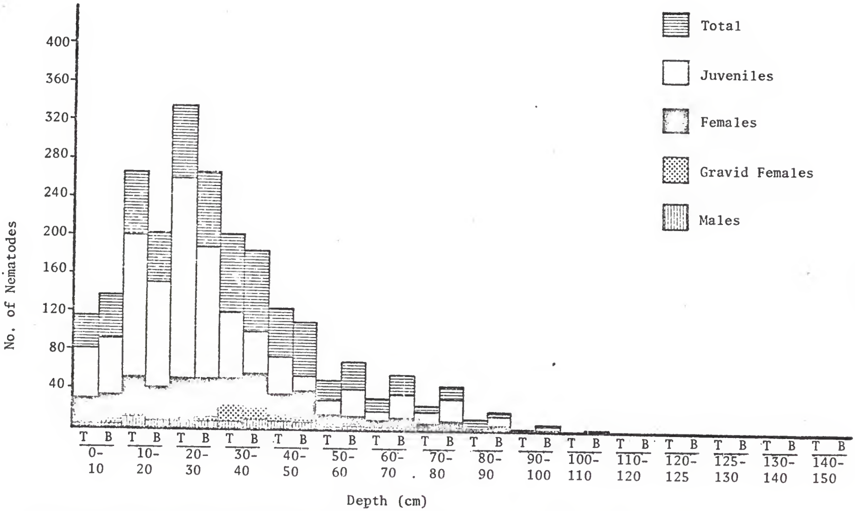


Figure 17. Mean vertical distribution of *Trichodorus proximus* in PVC columns with 1.25 m water tables (T=nematodes introduced at top of column; B=nematodes introduced at bottom of column)

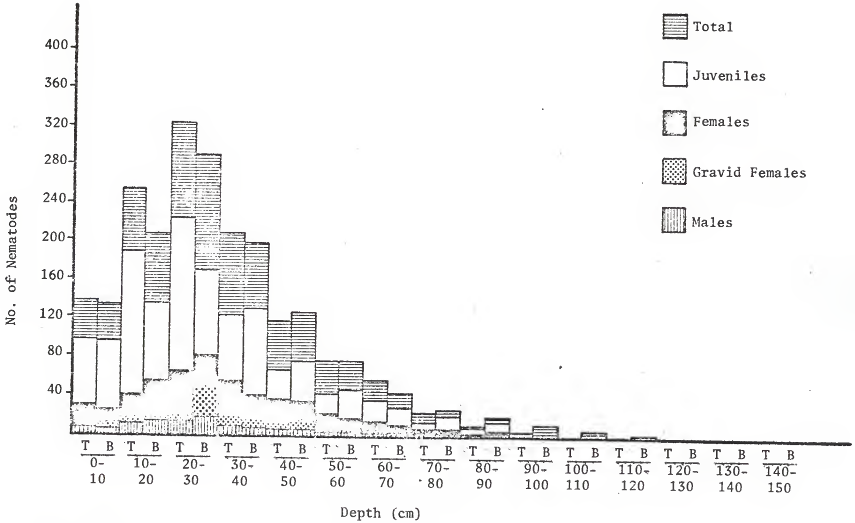


Figure 18. Mean vertical distribution of *Trichodorus proximus* in PVC columns with 1.5 m water tables (T=nematodes introduced at top of column; B=nematodes introduced at bottom of column)

Table 6.

Correlation of Populations of *Trichodorus christiei* in vertical PVC columns with soil depth and soil moisture: Correlation Coefficients / Prob lRl under HO: RHO = 0

	Total Nematodes	Juveniles	Females	Gravid Females
Soil Depth	-0.156220	-0.133945	-0.196161	-0.220634
	0.0443	0.0854	0.0119	0.0050
Soil Moisture	-0.136367	-0.153670	0.021988	-0.070669
	0.0797	0.0479	0.7779	0.6250

Table 7.

Correlation of Populations of *Trichodorus proximus* in vertical PVC columns with soil depth and soil moisture:
Correlation Coefficients / Prob 1R1 under H0: RHO = 0

	Total Nematodes	Juveniles	Males	Females	Gravid Females
Soil Depth	-0.786479 0.0001	-0.792284 0.0001	-0.763019 0.0001	-0.775337 0.0001	-0.647005 0.0001
Soil Moisture	-0.509476 0.0001	-0.506767 0.0001	-0.336226 0.0001	-0.388389 0.0001	-0.270070 0.0008

Effects of Soil Moisture on Survival and Reproduction of *Trichodorus Christiei* and *T. proximus*

In laboratory tests, *T. christiei* survived and reproduced significantly (P>0.01) better at 10% moisture than at 0, 20, 30, or 40% moisture levels (Table 8; Fig. 19). In fact, no specimens survived at 0% moisture and only one juvenile survived at 40% moisture. *T. proximus* survived and reproduced significantly (P>0.05) better at moisture levels of 10% and 20% than at other levels (Table 9; Fig. 20). So specimens survived at 0% moisture and very few survived at 40% moisture.

Effects of Soil Collected From Different Depths on Survival and Reproduction of *Trichodorus christiei* and *T. proximus*

The textures of the soils used in this test are listed in Table 10. Arithmetic means of nematode population numbers are listed in Tables 11 and 12. Populations of *T. christiei* and T. proximus were significantly (P>0.05) higher in pots filled with soils collected from more shallow depths in the field. *T. christiei* populations were higher in soil collected from 0 to 90 cm, while *T. proximus* populations were higher in soil from 0 to 80 cm.

Movement of *Trichodorus christiei* and *T. proximus* Through Soil

Thirty-six hours after being introduced into the center of a "migration box", an average of 15% of the *T. christiei* (Fig. 21, 22) and 39% of the *T. proximus* (Fig. 21, 23) had moved to the root zone of the bait plant located 25 cm from the point of inoculation. Seventy-two hours after inoculation, an average of 44% of the *T. christiei* (Fig. 21, 24) and 56% of the *T. proximus* (Fig. 21, 25) had moved to the root zone. Relatively few nematodes were found in any of the 5 X 10 cm recovery sections outside a band 15 cm on either side of a straight line between

Table 8

Correlation of laboratory populations of *Trichodorus christiei* with soil moisture (t values)

Treatment	Total Nematodes	Juveniles	Females	Gravid Females
10% X 20%	10.82**	11.64**	1.44	4.33**
10% X 30%	28.75**	30.83**	6.70**	13.44**
10% X 40%	30.71**	32.70**	7.37**	14.23**
20% X 30%	18.26**	16.20**	4.76**	5.06**
20% X 40%	20.58**	18.09**	5.42**	5.45**
30% X 40%	11.15**	10.58**	3.84**	1.63

**significant at 0.01 level

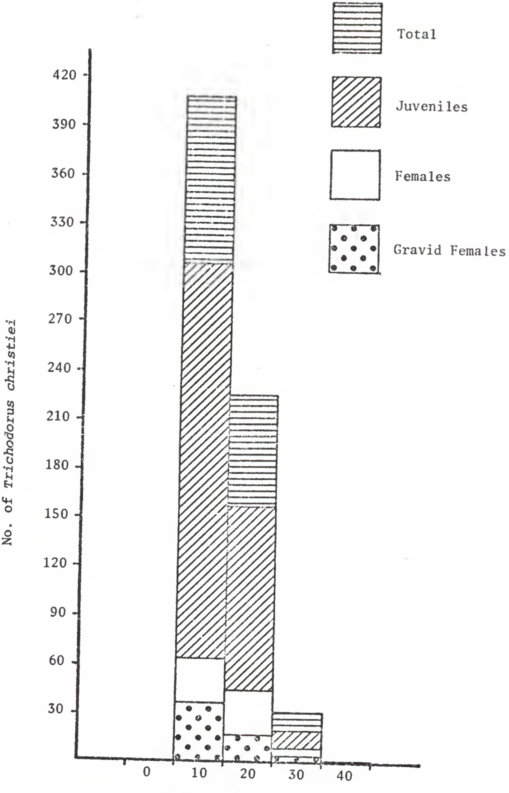


Figure 19. Effects of soil moisture on survival and reproduction of *Trichodorus christiei;* 100 specimens used as inoculum

Table 9.

Correlation of laboratory populations of *Trichodorus proximus* with soil moisture (t values)

Treatment	Total Nematodes	Juveniles	Males	Females	Gravid Females
10% X 20%	0.33	0.52	0.78	0.25	0.79
10% X 30%	4.10**	4.11**	2.65*	3.62**	0.91
10% X 40%	7.44**	6.87**	5.14**	8.27**	2.31
20% X 30%	7.01**	6.97**	4.41**	2.57	0.24
20% X 40%	12.60**	13.11**	7.37**	5.46**	2.09
30% X 40%	13.10**	4.99**	4.10**	7.21**	1.68

* significant at 0.05 level
** significant at 0.01 level

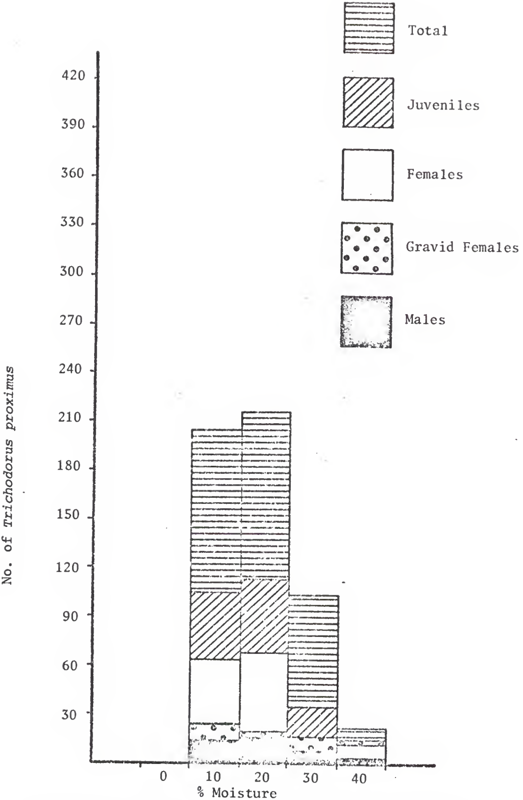


Figure 20. Effects of soil moisture on survival and reproduction of *Trichodorus proximus;* 100 specimens used as inoculum

Table 10.

Texture of soil from Bed Four,
Yelvington farm (new land), ARC Hastings, Florida

Soil Depth (cm)	% Sand	% Coarse Silt	% Fine Silt	% Clay
0-10	91.7	3.7	1.9	2.7
10-20	91.4	4.0	2.2	2.4
20-30	90.6	4.4	2.6	2.4
30-40	91.3	3.9	2.9	1.9
40-50	90.1	4.6	3.4	1.9
50-60	90.5	4.2	2.7	2.6
60-70	91.6	3.6	2.5	2.3
70-80	92.1	3.3	2.2	2.4
80-90	92.0	3.7	2.3	2.0
90-100	91.6	3.4	2.6	2.4
100-110	90.6	3.8	2.7	2.9
110-120	92.0	3.2	2.6	2.2
120-130	88.6	3.7	2.7	5.0
130-140	91.4	3.4	2.3	2.9
140-150	92.8	3.0	2.2	2.0

Table 11.

Effects of soil collected from different depths on Survival and Reproduction of *Trichodorus christiei* (mean of 6 replicates)

Depth from which Soil was Collected	Total Nematodes	Juveniles	Females	Gravid Females
0-10	2353^a	1972	345	36
10-20	2360^a	2001	336	23
20-30	2327^a	2011	293	23
30-40	2142^a	1816	307	19
40-50	2037^a	1725	287	25
50-60	1764^a	1577	165	23
60-70	1859^a	1659	180	20
70-80	1689^a	1475	197	17
80-90	1723^a	1524	184	16
90-100	1414^b	1218	176	21
100-110	1467^b	1261	190	16
110-120	1565^b	1373	173	19
120-130	1615^b	1411	182	23
130-140	1443^b	1252	175	15
140-150	1527^b	1318	188	21

a = no significant difference within "a" group
b = no significant difference within "b" group
a X b = significant difference at 0.05 level

Table 12.

Effects of soil collected from different depths on
Survival and Reproduction of *Trichodorus proximus* (mean of 6 replicates)

Depth from which Soil was Collected	Nematodes	Juveniles	Males	Females	Gravid Females
0-10	1701^a	1242	37	373	49
10-20	1545^a	1124	41	340	40
20-30	1553^a	1166	42	316	30
30-40	1635^a	1190	38	365	43
40-50	1525^a	1152	30	308	36
50-60	1521^a	1215	15	267	24
60-70	1404^a	1099	15	264	26
70-80	1423^a	1058	17	323	23
80-90	1258^b	966	19	248	27
90-100	1193^b	880	25	261	28
100-110	1260^b	971	25	237	27
110-120	1032^b	716	32	260	24
120-130	1185^b	919	26	214	27
130-140	1165^b	878	29	237	22
140-150	1114^b	822	30	242	20

a = no significant difference within "a" group
b = no significant difference within "b" group
a X b = significant difference at 0.05 level

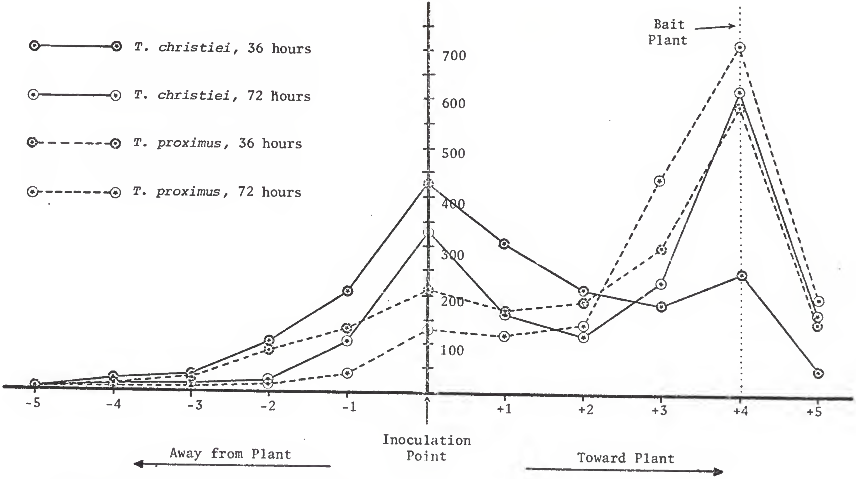
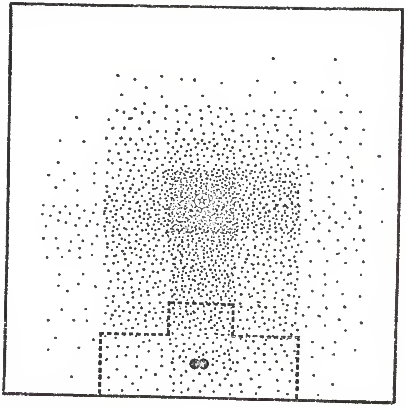


Figure 21. Horizontal movement of *Trichodorus christiei* and *T. proximus* from an inoculation point toward the root zone of a Rutgers tomato plant (recovery zones correspond with those shown in Figure 7.)



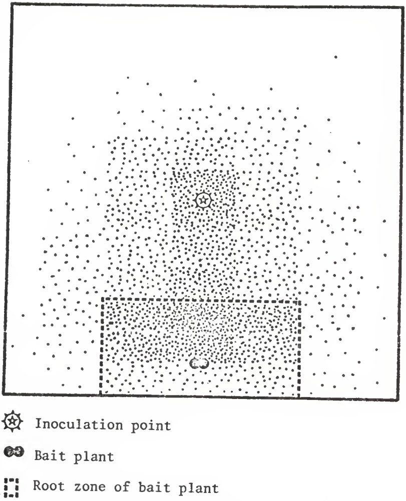
✪ Inoculation point

● Bait plant

⬚ Root zone of bait plant

Each dot represents one nematode

Figure 22. Distribution of *Trichodorus christiei* in horizontal movement box 36 hours after inoculation into the center of the box



Each dot represents one nematode

Figure 23. Distribution of *Trichodorus proximus* in horizontal movement box 36 hours after inoculation into the center of the box

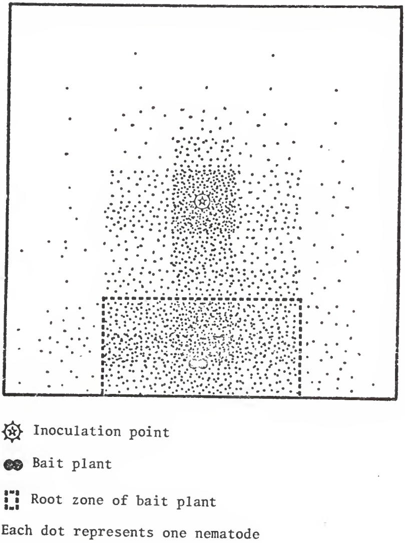
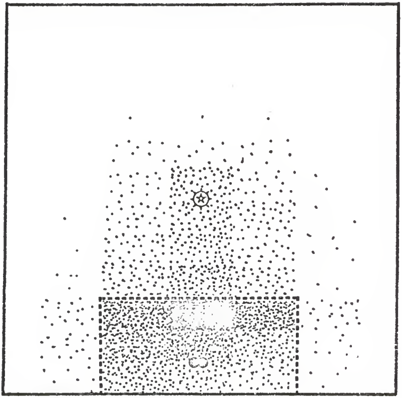


Figure 24. Distribution of *Trichodorus christiei* in horizontal movement box 72 hours after inoculation into the center of the box



✪ Inoculation point

∞ Bait plant

⬚ Root zone of bait plant

Each dot represents one nematode

Figure 25. Distribution of *Trichodorus proximus* in horizontal movement box 72 hours after inoculation into the center of the box

the inoculation point and the root zone of the bait plant.

Determination of Soil Properties

No significant differences between soil layers were noted for particle density, bulk density and porosity (Table 13) or for soil texture (Table 10). Organic matter decreased significantly ($P>0.05$) as soil depth increased (Table 13), except at the 110 to 120 cm layer, in which it was significantly ($P>0.05$) higher than surrounding layers - a characteristic of Rutlege soils (12).

Isolation of Tobacco Rattle Virus

Examples of corky ringspot-affected Sebago potato tubers used as inoculum are illustrated in Figures 26 and 27.

No test plants exhibited virus induced symptoms after mechanical inoculation with suspected TRV-infected tissue samples (Table 14), or after secondary inoculations of some of the original test plants into a second series of test plants (Table 15).

Attempts failed to transmit TRV to bait palnts by using *T. christiei* and *T. proximus* collected from fields having high incidences of corky ringspot (Table 16). Numbers of nematodes recovered from such tests were almost always lower than numbers used as inoculum.

Electron microscopic examinations of leaf extracts of *Capsicum annuum* L. 'California Wonder', *Lycopersicon esculentum* 'Rutgers', *Nicotiana glutinosa* L. and *N. tabacum* 'Samsun NN', which has all been inoculated with expressed sap from CRS-affected Sebago potato tissues, revealed no TRV particles. Examinations of two tuber samples and two sprout samples each of Pungo and SEbago potatoes, all eight to ten weeks old and exhibiting CRS symptoms, revealed no TRV particles.

Table 13.

Properties of soil from Bed Four, Yelvington farm (new land),
ARC Hastings, Florida (mean of 6 replicates)

Soil Depth (cm)	Particle Density	Bulk Density	Porosity	% Organic Matter
0-10	2.84(2.80-2.90)*	1.31(1.26-1.37)	53.97(51.59-55.63)	2.08(1.94-2.21)
10-20	2.54(2.40-2.60)	1.33(1.29-1.39)	47.80(45.42-50.38)	1.04(0.36-1.42)
20-30	2.52(2.33-2.59)	1.30(1.28-1.33)	48.31(43.78-50.58)	1.14(0.81-1.35)
30-40	2.60(2.55-2.62)	1.32(1.29-1.34)	49.35(48.24-50.76)	1.89(1.71-2.16)
40-50	2.55(2.34-2.74)	1.31(1.27-1.34)	48.64(44.44-53.65)	0.91(0.09-1.97)
50-60	2.53(2.43-2.60)	1.33(1.29-1.35)	47.65(44.44-50.19)	1.28(0.97-1.61)
60-70	2.57(2.50-2.65)	1.29(1.28-1.30)	49.76(48.40-51.32)	1.46(1.23-1.67)
70-80	2.59(2.50-2.71)	1.29(1.29-1.30)	49.97(48.40-52.03)	1.14(0.99-1.26)
80-90	2.50(2.43-2.62)	1.29(1.28-1.32)	48.21(46.34-51.15)	1.18(0.89-1.52)
90-100	2.53(2.49-2.58)	1.29(1.27-1.30)	49.27(48.19-50.39)	1.15(0.90-1.44)
100-110	2.58(2.55-2.63)	1.29(1.27-1.30)	49.76(48.40-51.71)	0.55(0.35-0.70)
110-120	2.53(2.45-2.59)	1.30(1.26-1.33)	48.49(46.53-51.35)	1.34(0.98-1.52)
120-130	2.54(2.44-2.85)	1.27(1.25-1.28)	49.78(47.54-56.14)	0.63(0.27-0.89)
130-140	2.51(2.41-2.58)	1.33(1.29-1.39)	47.06(44.81-48.84)	0.70(0.45-0.80)
140-150	2.55(2.49-2.58)	1.31(1.20-1.32)	48.52(47.79-49.22)	0.63(0.36-0.99)

* - mean (extremes)

Figure 26. External symptoms of corky ringspot on *Solanum tuberosum* 'Sebago'

Figure 27. Internal symptoms of corky ringspot on *Solanum tuberosum* 'Sebago'

Table 14.

Reactions of test plants to inoculation with sap from suspected TRV-infected tissue samples (data represent 6 replicates)

Test Plant	Source of Inoculum	
	Tubers	Sprouts
Capsicum annuum 'California Wonder'	-*	-
C. frutescens 'Tabasco'	-	-
Chenopodium amaranticolor	-	-
Cucumis sativus 'Chicago Pickling'	-	-
Cyamposis tetragonoloba	-	-
Datura stramonium	-	-
Gomphrena globosa	-	-
Lycopersicon esculentum 'Rutgers'	-	-
Phaseolus vulgaris 'Red Kidney'	-	-
Nicotiana clevelandii	-	-
N. glutinosa	-	-
N. tabacum 'Samsun NN'	-	-

* - indicates no symptoms observed

Table 15.

Reactions of test plants to inoculation with sap from plants previously inoculated with sap from suspected TRV-infected tissue samples (data represent 2 replicates)

Test Plant	Source of Inoculum	Host Reaction
Capsicum annuum 'California Wonder'	*C. annuum* 'California Wonder'	-*
Chenopodium amaranticolor	*C. amaranticolor*	-
Cucumis sativus 'Chicago Pickling'	*C. sativus* 'Chicago Pickling'	-
Nicotiana tabacum 'Samsun NN'	*N. tabacum* 'Samsun NN'	-

* - indicates no symptoms observed

Table 16.

Results of attempts to isolate TRV from plants fed upon by the nematodes *Trichodorus christiei* and *T. proximus* (data represent 6 replicates)

Nematode sp.	Inoculum Level	Bait Plant	Reaction of Assay Plant
Trichodorus christiei	10	*Cucumis sativus*	-*
T. christiei	100	*C. sativus*	-
T. christiei	10	*Nicotiana tabacum*	-
T. christiei	100	*N. tabacum*	-
T. proximus	10	*C. sativus*	-
T. proximus	100	*C. sativus*	-
T. proximus	10	*N. tabacum*	-
T. proximus	100	*N. tabacum*	-

* - indicates no symptoms observed

Electron microscopic examination of a separate group of CRS-affected Sebago tubers immediately after harvest revealed the presence of many virus particles in the form of flexious rods (Fig. 28). Of a total of 72 particles measured, 58% were between 493 and 599 cm in length, which is within the range of the Potato Virus X group. No TRV particles were observed.

Reactions of test plants inoculated with pehnol extracts are given in Table 17. The symptoms observed on *Chenopodium amaranticolor* Coste and Reyn. test plants were numerous necrotic and chlorotic lesions which tended to spread systemically to leaves immediately around the inoculated leaves. Symptoms were observed in five to six days. Symptoms observed on *N. glutinosa* test plants consisted of numerous pinpoint lesions and distortion of the inoculated leaves. Symptoms were observed in seven to eight days. No systemic symptoms were observed on *N. glutinosa*. These symptoms, which are typical for TRV (29), and the failure to isolate stable TRV, were considered evidence for the presence of the unstable form of TRV in the CRS-affected potato tissues tested.

Figure 28. Virus particles observed in corky ringspot-affected Sebago tubers

Table 17.

Results of Test plants to inoculation with phenol extracts from Corky ringspot-affected Sebago potatoes (data represent 2 replicates)

Test Plant	Source of Extract			
	Tubers	Tubers (dil. 1:10)	Sprouts	Sprouts (dil. 1:10)
Capsicum annuum 'California Wonder'	-*	-	-	-
Chenopodium amaranticolor	-	-	+	+
Datura stramonium	-	-	-	-
Gomphrena globosa	-	-	-	-
Nicotiana glutinosa	+	+	+	+
Nicotiana tabacum 'Samsun NN'	-	-	-	-

* - indicates no symptoms observed
+ - indicates symptoms observed

DISCUSSION

The Yelvington farm populations of *T. christiei* and *T. proximus* exhibited nonsignificant fluctuations throughout the year. Populations of both species showed peaks just after the end of the potato-growing season, when weeds had begun to become established in the field. Laboratory studies testing the pathogenicity of *T. christiei* and *T. proximus* revealed that Sebago and Pungo potatoes are poor hosts for both nematode species. Therefore, no significant field population increases were expected during the potato-growing season. Population levels dropped during the period when the soil was most exposed to solar heat and to rapid fluctuations in soil moisture due to summer rains. These population drops probably were a result of high soil temperatures and fluctuating moisture levels since *T. christiei* is known to reproduce readily on sorghum and on many weeds commonly occurring on the Yelvington farm (62). Nematode populations began to stabilize after the cover crop was well-established and summer rains had begun to dissipate.

Soil-inhabiting nematodes are essentially aquatic animals, living in microfilms of water, and marked changes in population density have often been attributed to changes in the moisture content of the soil (8, 15). In this study, field populations of *T. christiei* and *T. proximus* exhibited highly significant negative correlations with soil moisture. Periods of highest population density coincided with periods of low moisture (10% to 25%) while periods of low population density corresponded with periods of high soil moisture (above 25%). These results were in complete agreement with laboratory data, which revealed most favorable moisture levels of 10% for *T. christiei* and 10% to 20% for *T. proximus*. *T. proximus* reproduced as well at 20% moisture as at 10% moisture and appeared to be more tolerant of higher soil moisture levels both in the laboratory tests and in the field than was *T. christiei*. Collis-George (18), Van Gundy and Stolzy (76), Wallace (83) and Kable and Mai (41) have suggested reasons for higher population densities in drier soils: (a) nematodes can move more freely in moist than in dry soil, therefore expending their energy reserves more rapidly in wetter soil; (b) in dry soil the osmotic potential of the water present is higher than in wet soil, probably closer to that of the nematode: therefore energy utilization is less; (c) toxin production by anaerobic bacteria can cause nematode mortality in saturated soil; (d) the oxygen supply may be limiting in saturated soil; and (e) dry soils inhibit the growth and movement of many microbial organisms pathogenic to nematodes.

Nematode populations were, on the whole, not significantly correlated with soil pH. The juveniles of *T. christiei*, however, showed significant negative correlation with pH. This may have been due to higher pH levels during periods of high soil moisture and lower pH levels in periods of low soil moisture. The effect of soil pH on nematode populations has been reported, but results are often inconclusive and contradictory. The lack of data and the conflicting nature of that already published accentuates the need for further research in this area of nematode ecology. The task will not be easy, however, because, as Wallace (83) points out, nematodes alter the pH of the soil they inhabit, and thus it is difficult to obtain a true correlation between pH and nematode populations.

In any field problem dealing with nematode population dynamics, it is necessary to determine the physical properties of the soil environment. There are many references to correlations between the distribution and abundance of various plant parasitic nematodes and the physical properties of the soil from which they were recovered. The laboratory populations of *T. christiei* and *T. proximus* showed a significant correlation with soil collected from various depths in the field. Fewer nematodes survived and reproduced in soil collected from greater depths than in soil collected from nearer the surface. The physical structure of the soils did not vary significantly among the depths, but differences in the compaction of the soils were noted: soils collected from greater depths tended to become harder and more compact than did soils from nearer the surface. This compaction probably inhibited the movement of the nematodes, thereby reducing their reproductive rates. Brodie and Quattlebaum (11) found this to be true with *T. christiei*. Fidler and Bevan (27), Ferris and Bernard (26), Jones, Larbey and Parrott (40) and Kimpinski and Welch (43) stressed that the water holding capacity of a soil type was more important than the soil type itself on population densities of several plant parasitic nematodes. In my tests, more organic matter was in the soil nearer the surface than deeper, with one exception. The better water holding capacity of organic matter may have been a factor in my tests.

Competition for food is a factor which could have reduced the survival rates of *T. christiei* and *T. proximus* in the field (75, 84). Field population levels of other plant parasitic nematodes, especially *Belonolaimus longicaudatus* and *Helicotylenchus dihystera*, were very high during the study, and these nematodes certainly competed for feeding sites. Root tips fed upon by *B. longicaudatus* and *Trichodorus* spp. cease to grow. *T.*

christiei populations have been found to decrease rapidly after host plants no longer produce new root tips (15).

An additional consideration in elucidating *T. christiei* and *T. proximus* population variations was diseases, parasites and predators. These may include such diverse groups of organisms as viruses, bacteria, fungi, protozoans, tardigrades, turbellarians, enchytraeids and arthropods (15). Further investigations would be required to determine the presence of these organisms on the Yelvington farm and their possible effects on *T. christiei* and *T. proximus*. There is no reason to doubt their presence and effects, however, since all or some are present in almost all soils.

Field and laboratory populations of *T. christiei* and *T. proximus* exhibited a significant negative correlation with soil depth. Field populations of *T. christiei* were most dense at 10 to 40 cm while laboratory populations were most dense at 10 to 60 cm. *T. proximus* populations were most dense at 20 to 50 cm in the field and at 10 to 40 cm in the laboratory. Since the laboratory and the field data were correlated and since the nematode populations were highly correlated with soil moisture, it may be that the nematode populations stayed in these soil areas because the soil was insulated against rapid changes in the microclimate. This is in agreement with the findings of several other authors who have suggested that some species have an optimum portion of the soil profile, independent of root distribution, in which they are most frequently found (31, 72, 73, 87). Generally, however, the literature states that most nematode species have been recovered in greatest numbers from the top 20 cm of soil (20, 54, 68).

In both field and laboratory studies, no specimens of *T. christiei* or *T. proximus* were found below the soil water table, indicating, certainly, that saturated conditions are unfavorable. The fact that there were no significant differences between laboratory populations in PVC columns inoculated at the top of the column and those inoculated at the bottom of the column through the water table indicates that both species can tolerate high moisture levels for a time, but they move rapidly into more suitable areas. Movement through soil water may be one means of spread under field conditions. Dispersal by run-off of water and by irrigation has been described as a primary contributing factor in the rapid spread of some nematodes (24, 25, 52, 67).

Tests investigating the movement of *T. christiei* and *T. proximus* through soil revealed that significant numbers of both species moved in a narrow band from the inoculation point to the root zone of the bait plant, indicating not only attraction, but also a relatively direct approach to the plant. This supports the hypothesis of several authors (55, 77, 81, 82) that explains nematode attraction in terms of their orientation in concentration gradients of some stimulus emitted by the root and acting at a distance.

The rate of movement of *T. proximus* was much faster than that of *T. christiei* possibly because of some basic metabolic difference or, more likely, because *T. proximus* is much larger in size than *T. christiei*. However, at the rate of movement revealed in these laboratory tests, it appears possible that both *T. christiei* and *T. proximus* could move distances of 73 m or more in a year. This represents a tremendous potential for spread throughout a geographical area and may help to explain the widespread occurrence of CRS in areas with very low *Trichodorus* population levels.

Reports of work with the Hastings, Florida isolate of tobacco rattle virus have agreed that isolation of TRV from corky ringspot-affected potato tubers may be accomplished within a period of four to six weeks after harvest, with the ease of isolation rapidly decreasing during that period (30). After that time, transmission is rarely accomplished using ordinary methods of mechanical inoculation (30).

The data presented here show that no TRV isolation was accomplished using mechanical inoculation and electron microscopic techniques. This was to be expected since the potatoes used as inoculum had been harvested eight to sixteen weeks prior to inoculation attempts. Subsequent tests showed that inoculation of phenol extracts from the same potatoes resulted in the appearance of TRV-like symptoms in test plants. These data, along with the previous reports of a progressive decrease in infectivity of Hastings TRV with an increase in the age of the infection (30), lead to the conclusion that the original infection is the result of complete, stable virus particles which are progressively degraded to incomplete, unstable components. This is in complete agreement with reports of work with other isolates of stable and unstable TRV (as summarized in the introductory portion of this paper).

In nematode transmission experiments, the failure to obtain symptoms on indicator plants may have been due to the failure of the nematodes to transmit TRV to the bait plants, or possible due to the presence of only the unstable form of TRV in the bait plants, thereby reducing the chances of obtaining normal mechanical transmission to indicator plants, or the nematodes simply may not have been viruliferous.

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BIOGRAPHICAL SKETCH

Robert E. Harrison was born in Shreveport, Louisiana on 11 March 1947. He attended public schools in Louisiana and California, U.S.A. and in Libya. He graduated from Bossier High School, Bossier City, Louisiana in 1965. In 1970, he received the degree of Bachelor of Science in Zoology and in 1972 the Master of Science in Zoology degree, both from Louisiana Tech University. In the fall of 1972, he began studies toward the degree of Doctor of Philosophy in Entomology and Nematology at the University of Florida. He is a member of Sigma Xi, Gamma Sigma Delta, Beta Beta Beta, the Society of Nematologists and the Indian Society of Nematologists.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Grover C. Smart, Jr.

Grover C. Smart, Jr.
Chairman
Professor (Nematologist)

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

VG Perry

Vernon G. Perry
Professor (Nematologist)

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

F. W. Zettler
Professor (Plant Pathologist)

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

D. P. Weingartner
Assistant Professor (Plant
Pathologist)

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1975

Jack L. Fry
Dean, College of Agriculture

Dean, Graduate School